A SURVEY TO DOCUMENT THE DECLINE STATUS OF THE SUGAR MAPLE FOREST OF ONTARIO: 1986

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A SURVEY TO DOCUMENT THE DECLINE STATUS OF THE SUGAR MAPLE FOREST OF ONTARIO: 1986

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I EXECUTIVE SUMMARY

Air pollutants are alleged to contribute to regional forest decline. However, single causal factors are often difficult to identify and usually the decline is attributed to a multi-causal relationship in which many stresses act on the forest ecosystem either cumulatively or synergistically to precipitate a decline episode.

Forest decline has been reported historically, however the severity and extent of decline has become more apparent, particularly in the last 10 to 15 years. In 1985, the Ontario Ministry of the Environment initiated a province-wide study of the condition of Ontario's hardwood forest. The study objectives were: 1) to establish a network of permanent observation plots and evaluate the trees as to their decline status, 2) to develop a rating system to assess the condition of hardwood trees, and 3) to evaluate the assessment data and determine if regional differences are apparent in forest tree condition. Sugar maple was the primary target species, although all hardwood tree species encountered in the survey plots were evaluated. This was a survey of hardwood forest decline conditions in Ontario and determination of causal factors was not an objective.

The survey was conducted under contract to Ecological Services for Planning Ltd. of Guelph. In total, 110 plots consisting of 100 trees greater than 10 cm at breast height were established and the initial evaluation of 11,000 trees was completed in July and August 1986. The plots were located throughout the hardwood forest zone of Ontario. The trees were evaluated using a numerical Decline Index rating system which transformed qualitative assessments of tree condition into quantitative data which could be tested statistically. Additional data regarding gross soil characteristics, stand mensurational characteristics, disease and insect activity and the frequency of tree stem defects was also collected.

Hardwood forest decline was scattered in isolated areas in Ontario although regional patterns were evident.

Generally, trees in Northern Ontario tended to be in somewhat poorer condition than those in Southern Ontario, although the southwestern area of the province also had a higher frequency of declining trees. The survey plots located through the central part of the province from Lake Huron across the north of Lake Ontario to Kingston and Ottawa consistently contained trees in good condition with a low frequency of decline. Two separate statistical analysis methods were used to confirm the regional decline pattern.

Although sugar maple was the survey target species, 22 additional tree species were encountered in the plots. Ranked in order of decline severity, the tree species which comprised greater than 1% of the sample population are: sugar maple < beech < white ash < basswood < yellow birch = red oak < red maple < ironwood < white birch < black cherry.

The plots established and evaluated in this study are permanent forest observation plots. When the survey is repeated in the future, the data will yield both a temporal and spacial picture of the condition of Ontario's hardwood forest resource.

II INTRODUCTION

In recent years some of the damage observed in forest ecosystems has been attributed to anthropogenic air pollutants. Sulphur dioxide (SO_2) and various nitrogen oxides (NO_x) are created in industrial and urban centres of the United States and Canada and deposited over hundreds, or even thousands, of kilometers according to prevailing winds and seasonal weather patterns. Ozone has also been shown to adversely affect crop productivity in Ontario, and is suspected to reduce growth of sensitive forest trees in high deposition zones.

Vegetation is constantly exposed to a wide range of natural environmental stresses such as drought, intense cold and heat, frost, and insect and disease epidemics. Man adds more stress through poor site management and air pollutants. These stresses often occur in combination and act synergistically so that their cumulative effect is much more potent. Therefore, it is usually difficult to identify single causal factors responsible for damage, decline, or productivity losses.

In this report, the term "atmospheric pollutants" will be used to refer to the entire range of common airborne pollution including wet and dry acidic deposition.

At last count, there were nearly 200 theories on the causes of forest decline. However, most are variations or regional examples of one of six major hypotheses. These hypotheses are: (1) general stress, (2) soil acidification and toxicity to roots, (3) ozone injury, (4) foliar nutrient leaching, (5) excessive fertilization and (6) growth altering organic compounds.

The general stress hypotheses suggest that the forests have been exposed to several decades of sub-acute air pollution mixtures. This decreases the photosynthetic efficiency of trees, reduces vigor and disturbs the energy budget. The production of phenols and terpenes within the tree are

reduced, therefore increasing susceptibility to insects, disease and other natural stress factors. The trees die of natural agents, thereby obscuring the anthropogenic connection.

The soil acidification and toxicity to roots hypothesis suggests that natural acidification of forest soils is accelerated by acidic deposition. Nutrients essential to tree growth are leached from the soil at a rate exceeding replacement, thereby inducing nutrient deficiencies. At the same time, potentially toxic elements like Al, increase in availability as soil pH decreases, causing root mortality. Reductions in fine root biomass inhibit the trees' ability to supply moisture and nutrients from the dwindling supply, resulting in crown dieback which mimics moisture and/or nutrient stress.

The ozone hypotheses suggest that photochemical oxidants directly incite tree decline by injuring the foliage through chronic ozone exposure. A reduction in photosynthetic capacity leads to reduced carbon assimilation and eventually to reduced fine root growth. Ozone injury causes the leaf cell membranes to be more permeable and therefore the cell constituents are more accessible to the leaching potential of wet acidic deposition.

The foliar nutrient leaching hypothesis expands on the foliar damage caused by chronic exposure to air pollutants and suggests that magnesium deficiency symptoms develop in the crown when these elements are lacking in the soil. Trials in Europe have been successful in reviving certain symptomatic trees by soil fertilization with the deficient element as diagnosed by foliar analysis.

Acidic deposition contains nitrogen as well as sulphur. The excessive fertilization hypothesis suggests that the forest may be over-fertilized with nitrogen and that trees may absorb nitrogen from atmospheric deposition directly through the foliage. Over-fertilization with nitrogen encourages rapid growth, creating a demand for additional nutrients which may not be available in the required amounts from the soil. Nitrogen over-fertilization also may result in late growth with reduced cold hardiness, thereby rendering the tree more susceptible to frost damage or winter injury.

The growth-altering organic compounds hypothesis is somewhat speculative. This theory recognizes that in addition to the "normal" air pollution components, there are numerous organic compounds in the atmosphere. Some of these compounds are, or may mimic, natural plant hormones such as ethylene, thereby possibly adversely altering tree growth.

Extensive dieback and mortality of several tree species have been reported since the 1970's in Europe. Until recently, concern centered on coniferous species, particularly fir and spruce; however, several hardwood species are now similarly affected. In North America, decline episodes of both hardwoods and softwoods have been recorded at intervals throughout this century. Decline of red spruce and balsam fir has been extensive in the Northeastern United States since the early 1980's. Sugar maple decline in Quebec has been widespread, and has increased since 1981.

Concern has recently been expressed regarding the possible role of atmospheric pollutants in the decline of forests in Ontario. In response, the Ontario Ministry of the Environment has initiated a series of projects to examine this problem within the Acidic Precipitation in Ontario Study (APIOS) program. One component study established under this program, the Hardwood Decline Survey, was intended to assess the degree and extent of existing damage to selected hardwood forest sites in the Great Lakes-St. Lawrence and Deciduous Forest Regions of Ontario.

This report documents the results of the Province-wide Hardwood Decline Survey conducted in 1986.

III STUDY OBJECTIVES

The objectives of this study were:

(1) to establish a network of permanent observation plots in which baseline data can be obtained regarding the condition of hardwood forest tree species (sugar maple was the primary target species).

(2) to develop a rating system to assess the condition of hardwood trees in regards to the symptomatology experienced in Ontario.

(3) to evaluate the assessment data and determine if regional differences are apparent in forest tree condition.

The survey was intended as an inventory of the current decline conditions. Identification of the cause of decline and the examination of the relationship with atmospheric pollutants were not objectives of this study although certain patterns may become apparent in analysis of the data. The plots were selected with the intention that they will be accessible for future periodic re-evaluation. Future surveys will provide both a temporal and a spacial perspective on the changes of the hardwood forest resource in Ontario.

Figure 1 illustrates the range of sugar maple in Ontario and the average wet sulphate deposition.

IV PLOT ESTABLISHMENT

(a) Site Selection

The Hardwood Decline Survey was conducted under a contract awarded to Ecological Services for Planning Limited of Guelph, Ontario in 1985 and 1986. All field work including plot selection, establishment and evaluation was completed by the company in consultation with Ministry

of the Environment scientific staff. Plot selection followed both general and specific criteria established by the Ministry.

The general criteria included representative coverage of the geographic distribution of sugar maple (the target species) in the Province of Ontario. To this end, documents and maps were collected for the study area, including 1:50,000 topographic maps, Forest Resources Inventory (F.R.I.) composite stand maps, and 1:10,000 air photos where available. A preliminary mapping exercise was conducted to narrow down the area suitable for baseline field plots. Buffer zones were drawn about urban centres and point sources of air pollution on the topographic sheets, and sugar maple stands suitable for investigation were identified on the F.R.I. base.

Once the initial mapping exercise was complete, candidate sites for permanent plot installation were investigated further in interviews with local Ministry of Natural Resources forestry staff. Past and projected management activities on candidate sites were determined at the interviews. Each of these areas was then inspected in the field to test for conformity to plot selection criteria.

Specific criteria for plot selection were as follows:

(1) greater than 50% sugar maple;

(2) stand greater than 10 hectares;

(3) stand age of 75 to 150 years;

(4) good access to accommodate re-evaluation;

(5) relatively undisturbed in the last 20 years with no scheduled cutting during the next 20 years;

(6) more than 10 km from an urban area or point source of air pollution;

(7) public ownership, or an Agreement Forest, was preferred;

(8) plots te be located at least 30 metres from any woodlot edge.

There were 110 plots established. Each plot consisted of 100 trees greater than 10 cm diameter breast height. Therefore the survey was based on a sample of 11,000 trees.

(b) Plot Installation

Permanent sample plots were laid out in the following manner. A pressure-treated 4" x 4" post was placed at the plot centre and a plot identification tag attached. The tree closest to the centre post and located true north was identified as Tree No. 1. An engineer's transit was set up over the plot centre and aligned to this tree. One hundred trees of all species over 10 cm DBH were then numbered in a roughly circular area around the plot centre. All trees in the plot were sequentially numbered and referenced with an angle and distance measurement relative to the plot centre. The trees were numbered with an aluminium tag fixed at breast height and the tree number was marked on the tree with paint (except where this conflicted with the land owner's wishes).

All plots were located and mapped using standard MNR references, such as Township and stand number in northern Ontario, and Township and compartment number in southern Ontario. Reference maps showing details of each plot location were also prepared.

Plot establishment was initiated in late July 1985 at which time assessment trials were also conducted. The remaining plots were established early in the 1986 growing season and all 110 plots were assessed in July and August 1986. Figure 2 illustrates the distribution of the 110 baseline survey plots in Ontario.

V PLOT EVALUATION

At the time of installation, all plots were described and mapped according to a prescribed form (sample as Appendix I). The data included information regarding plot slope, aspect, rock outcrops, stoniness, soils data, and stand mensurational data.

Soils were described at each of the 110 plots in the following manner. A standardized format based on the Agriculture Canada CANSIS Manual for Describing Soils in the Field and the Ontario Institute of Pedology Soils Field Guide was adopted. A soil pit approximately 1m x 1m x 1m was dug near the plot centre. From the pit, appropriate soil features were recorded. Soil features described included soil horizons, thicknesses, textures, Munsell colours, depth to free carbonates, depth of mineral soil over bedrock, depth to distinct mottles, prominent mottles, gleying and depth of organic matter. Soil moisture regime and internal drainage classes were interpreted from these data.

Additional checks for organic matter depth and depth to bedrock were conducted with an auger at a minimum of five additional locations within the established plot. Source documents for the description of soil features are included in Appendix II.

Five separate wedge prism sweeps were conducted with a metric basal area factor 2 prism in the area immediately surrounding each plot. Stand basal area, basal area by species, species composition and an estimate of percent crown closure were recorded. The species, total height and diameter breast height were recorded for each tree on the plot. All plot trees were assessed with crown condition ratings (crown evaluation methodology is explained on the next page).

Two systems of tree classification were developed by Environment Ministry scientists and used by the contractor to assess all the trees on each survey plot. The first system (Appendix IV) described a gradient of gradual crown decline on a scale of 1 (healthy) to 10 (dead) in increments of one. Although, subjective, this straightforward decline scale was useful in identifying relative differences in tree health. The second assessment methodology (Appendix III) involved a series of subjective ratings of decline symptoms common to Ontario. Estimates of the percentage of dead branches in the crown, the percentage of undersized leaves and the percentage of the crown which was either slightly or significantly chlorotic were made for each tree. These individual subjective ratings were combined in a formula designed to weight the foliar attributes proportional to the live crown and expressed tree condition on a numerical scale ranging from 0 (healthy) to 100 (dead tree). More detailed information on the numerical decline index rating system is provided in the following section on Data Handling.

In addition to the crown condition, the occurrence of defects such as cankers, frost cracks, logging wounds, fire scars and evidence of insect and disease activity also were recorded. (Example tally sheets are illustrated in Appendix V).

Field crews hired by the contractor were trained until consistent results were obtained with both assessment methodologies.

VI DATA HANDLING

All plot data recorded in the field were entered into an IBM-PC compatible microcomputer for compilation and statistical analysis, using either the Lotus 1-2-3 spreadsheet package, or Borland International's REFLEX database manager as the primary data entry tools. For each tree, the computer automatically calculated a 'decline index' based on the percentage of dead branches in the tree crown, the percentage of slight and/or strong chlorosis, and the percentage of undersized leaves. The exact formula used is as follows:

$$DI = DB + (A*UL) + (A*ST) + (A*SL/2)$$

where: DI = decline index
DB = percent dead branches
UL = percent undersized leaves
ST = percent strong chlorosis
SL = percent slight chlorosis
A = (100 - DB) /400

This decline index gives a scaled rating estimate of decline, with values ranging from 0 (no symptoms) to 100 (a dead tree). Healthy trees may have a decline index ranging from 0 to about 15. Trees exhibiting slight to moderate decline would typically have an index value between 15 and 30. Trees in a severe stage of decline would have a decline index of greater than 30. The greatest weight in the formula is given to the percentage of dead branches. Strong chlorosis and undersized leaves have a weighting that is proportional to the percentage of live branches in the tree. Slight chlorosis is given 50% of the weighting of strong chlorosis.

A summary data base was prepared for each plot. This included the mean and standard deviation for most variables, plus a frequency distribution and calculation of the median for the crown class rating system. This plot summary was prepared separately for each hardwood species. All statistical calculations (Means and standard deviations) for numbers in percentile form, including decline index, were analysed using an arcsine transformation (arcsine square root of percentage value).

Stem and Crown Maps

The computer was also used to generate a map of individual stem locations and crown sizes for the trees located within each of the 110 study plots. The centre of the diagram for each plot represents the 0,0 metre reference point for tree locations. Since the plots vary in size depending of the density of the stand, the scales for each diagram my be

different. Reference marks on the axes represent a distance of 1 metre. Stem locations are indicated by their corresponding tree numbers on the 'Tree Map' plots, which links the diagrams to the field data.

Crown sizes were plotted on the accompanying 'Crown Maps', and were estimated from the DBH measurements for each tree. Each tree species was plotted in a different colour for clarity. The diagram was intended to provide a visual overview of the relative arrangement of the tree crowns in the plot for determining possible competitive interactions and to facilitate tree relocation. Since crown widths were not measured in the field, the diagram may not correspond exactly to the real situation.

VII PLOT SITE AND SOIL CHARACTERISTICS

The plot location summary is presented in Table 1. It includes forest region and sector, Township with lot and concession, MNR administrative district, forest stand number, NTS topographic map number and UTM coordinates as well as applicable air photograph number for each plot. The forest site regions and geographic extent of sugar maple are shown in Figure 1. The actual plot locations are shown in Figure 2. The field soils data are summarized for each plot in Table 2.

A series of maps were produced to illustrate the distribution of key soil features related to soil buffering capacity in order to determine if relationships exist between those soil features and decline index at each of the 110 assessment plots.

Figure 3 shows 3 classes of soil depth to bedrock. These are:

i) 0-40 cm (very shallow)
ii) 41-100 cm (shallow)
iii) greater than 100 cm (deep)

Figure 4 shows 3 classes of depth to free carbonates in the soil profile, as follows:

i) 0-50 cm (strongly limey)
ii) 51-100 cm (weakly limey)
iii) greater than 100 cm (no carbonates encountered within control section).

The depth to bedrock and depth to free carbonates classes were selected based on the frequency distribution of these attributes within the survey data, and because of their similarity to standard soil survey mapping classes. Free carbonate was detected in only 21 soil profiles, primarily in southern Ontario sites.

Figure 5 illustrates 4 classes of mineral soil textures. The classes represent standard family particle size classes as follows:

i) Sandy, including all Sand and Loamy Sand textures
ii) Coarse Loamy, including the textures Loamy very fine Sand, all Silty Sands and Sandy Loams
iii) Silty, including the textures Silt, Silt Loam and Loam
iv) Fine Loamy or Clayey, including the textures Clay Loam, Silty Clay Loam, Sandy Clay Loam, Silty Clay and Clay.

The texture classes are ranked according to their approximate total Silt and Clay contents, and represent a gradient of increasing total soil water storage and buffering capacity.

VIII TREE CONDITION CHARACTERISTICS

The basic forest stand characteristics are summarized in Table 3. The mean and ranges for the tree parameters recorded for all species can be summarized as follows:

	DBH cm	Height m	Age* yr.	Basal Area m^2/ha	Crown Closure %
Mean	24.8	20.8	84	24.1	76
Minimum	16.8	14.5	60	14.0	50
Maximum	57.7	29.7	133	34.0	99

*from increment cores at breast height, and FRI data.

Although there was variability from plot to plot for the stand parameters, the data are sufficiently uniform to make comparisons of tree condition. The percentage of trees identified as sugar maple in the stands ranged from a low of 28% to high of 100% with an overall average of approximately 75%. Only 3 plots failed to meet the original objective of 50% maple and 2 of these were only marginally below the objective for maple composition.

Summaries of tree quality for all species and for maple alone are presented in Tables 4 and 5 respectively. The mean values for each plot for the assessment parameters (dead branches, slight and strong chlorosis, small leaves) are included in addition to the calculated decline index. Total numbers of all observed stem defects were also summarized. Most plots had about one defect per tree on average and, in some cases, nearly 3 defects per tree were present.

The geographic distribution of tree decline shown as a function of the decline index, for all species is presented in Figure 6 and for maples only in Figure 7. In these figures, the decline index was mapped as 6 classes, ranging from very low to severe. These classes were selected

on the basis of the frequency distribution of all decline index values. All of the classes mapped include approximately equal numbers of plots.

The mean decline index values for all species combined ranged from a minimum of 4 for a plot located in the Lindsay District, to a maximum of 29 for a plot located in Sault Ste Marie. Regional patterns of decline indices are apparent. Decline indices in Northern Ontario tend to be higher than those in Southern Ontario (North and South refers to MNR regions). Two separate areas of high decline values are also apparent. The first is located in Southern Ontario, and includes the Niagara, Chatham, Aylmer, and Simcoe districts. The other high decline area is located in Northern Ontario, and includes the Parry Sound, Muskoka, and Algonquin Park areas. A broad band of relatively healthy forest extends from Lake Huron north of Lake Ontario through Kingston and Ottawa.

The area of hardwood forest in Ontario is divided into two forest regions; the Deciduous and the Great Lakes St. Lawrence. These regions are further divided into 9 Forest Sections. These sectional divisions are based on vegetational units which reflect gross soil and macroclimatic regimes. The average decline index for each of the 9 forest sections was calculated, based on the hardwood survey plots located in each section. These data are summarized in Table 6. Statistical tests were conducted on the data to determine if the apparent regional differences in average decline index were significant. Using the Least Significant Difference method, average decline indices which vary by more than 4.7 are significantly different at $p \leq 0.01$. Therefore, only the lowest and highest average decline indices are significantly different. It can be stated with confidence that trees in the central and southeast portions of Ontario (mean decline index 10.9-12.1) are in better condition than those in the northern hardwood forest sections located in the Sudbury, North Bay and Georgian Bay area (mean decline index 15.7-17.3). Although the average decline index indicates a greater frequency of declining trees in the southwest, this difference is neither (statistically) worse than the central and southeast nor better than the northern forest sections. The regional decline index data are illustrated in Figure 8.

The mean decline index for each of the 23 tree species encountered on the 110 survey plots is listed in Table 7. Because of the radically different population sizes, these data were not statistically tested and therefore decline index differences between species are implied but not proven. In addition, 13 of the 23 species were tallied less than 100 times and therefore comprise less than 1% of the survey population. The decline index values reported for these species (black ash, bitternut hickory, trembling aspen, butternut, balsam poplar, white elm large tooth aspen, bur oak, weeping willow, pin cherry, shagbark hickory, green ash and white oak) are probably not representative of provincial conditions. Nonetheless, these data indicate that hardwood species other than sugar maple are experiencing decline and that, relatively speaking, sugar maple is in better condition (ie. exhibiting fewer decline symptoms) than most other hardwood trees in Ontario. In fact, if black ash and bitternut hickory are excluded because of small sample size, then sugar maple is ranked as the healthiest of the surveyed tree species. Listed in order of increasing decline index (i.e. deteriorating tree condition) for the tree species which comprised greater than 1% of the survey tally, the species are: sugar maple < beech < white ash < basswood < yellow birch = red oak < red maple < white birch < black cherry.

Table 8 lists the additional tree quality factors that were recorded for each sugar maple tree, totalled for all trees in each plot. These include defects such as frost cracks, wounds and the occurrence of insects and disease damage. The total number of sugar maples in each plot is also indicated. Frost cracks, open wounds and especially damage caused by insects, were frequently recorded on maple. The number of trees with observed pathogenic problems is certainly a low estimate due to the difficulty of documenting their presence by casual observation. However, the survey was not intended as a pathological inventory.

Mean decline index was tested for statistical correlation with the various observed defects to examine possible relationships between tree decline and wound type and frequency. The results of these tests are summarized in Table 9. These data suggest that the defects most commonly observed

on declining trees (statistically significant at $p<0.05$) in order of decreasing significance were cankers, feeding by mites, conks, open wounds and frost cracks. However, the data were not independently stratified, ie. trees which had cankers may also have had one or more of the other defects; therefore, it is not likely that any single defect is a significant contributing factor to decline. Rather, trees tend to become more prone to decline as defects accumulate. This was clearly illustrated when all defect observations for each tree were totalled and compared with decline index. The correlation coefficient for total defects vs decline index was highly significant, and in fact was considerably higher than the most significant single defect factor ($r = 0.575$ for total defects, $r = 0.417$ for cankers alone).

Similar statistical tests were conducted between tree decline index and tree DBH, age, basal area and crown closure. These stand parameters were not significantly correlated with decline index.

IX DETAILED ANALYSES - PLOT GROUPINGS

The next stage in the analysis was to evaluate differences in decline index between the plots, based on their locations and soils, using analysis of variance (ANOVAR) procedures. Plots were grouped into a database by different Forest Sectors and Ministry of Natural Resources Administrative Districts. Analyses of variance were conducted on mean decline index values for all tree species combined, using these grouping factors. Decline indices were transformed with the standard arcsine square root data transformation. This transformation is performed on estimates of proportions, with the object of making variance independent of the mean, for application of normal statistical procedures. It also tends to mediate the effect of under and over estimation at the low and high ends of the percent scale for subjective ocular field estimates. The results show F-ratios significant at the 99.9% probability level, for both Forest Sectors and MNR Districts, indicating that one or more groups, in each case, are significantly different from the others, with respect to decline index. Table 10 shows the results of the above ANOVAR.

Table 11 shows mean decline index values for each of the 27 MNR Districts, divided into two general groupings, Northern Ontario and Southern Ontario. District means are ranked within these zones in order of increasing decline index. In general, the highest and lowest values in these two tables are most likely to be significantly different from the other groups. For information purposes, ranked in order of mean decline index (i.e. deteriorating average tree condition), the MNR districts are: Lindsay < Maple < Wingham < Brockville < Cornwall < Owen Sound < Napanee = Blind River < Huronia < Bracebridge < Tweed < Simcoe < Brancroft = Pembroke < North Bay < Thunder Bay = Chatham = Carleton Place < Espanola < Aylmer < Cambridge < Niagara < Sudbury < Parry Sound < Algonquin < Minden < Sault Ste Marie.

Table 12 shows the results of the ANOVAR conducted on decline index values, using soil features as the grouping variable. The classes used in the analyses were the same as those defined on Figures 3, 4 and 5. In the case of soil depth (depth to bedrock) and depth to carbonates, continuous data could not be used since the absence of rock or carbonates cannot be defined. The 10 standard classes were used for soil moisture regime. The results are not significant for any of the soil variables. The soil classes do not discriminate differences in decline index, within the restrictions of the field sampling design.

Another statistical analyses method, a K-means clustering procedure, was used to further group the survey plots to identify which area in the province, or which groups of plots, were most alike or most dissimilar in regards to their decline characteristics. K-means clustering splits the data into a chosen number of groups, such that between group variation is as large as possible relative to within- group variation. The clustering was conducted on data from all 110 plots using transformed values for the attributes included in the calculation for decline index, i.e. percent dead branches, percent slight chlorosis, percent strong chlorosis and percent small leaves. Decline index was not included in the clustering, since it is a function of the other attributes. The K-means clustering was attempted for 5,6,7 and 8 groups. Greater than 6 groups simply

resulted in individual plots being split off from larger groups. Therefore, 6 groups was identified as the optimal number, since additional groups did not distinguish any new variation.

Table 13 summarizes the results of the K-means clustering of the decline data for six groups. At the top of the table is a summary of ANOVAR conducted between groups for each decline attribute. These are all significant at the 99.9% level, indicating that all attributes were used to discriminate the groups. The plot membership, plus descriptive statistics for the decline attributes within each of the six groups are listed in Table 13.

To illustrate the logic behind the K-means clustering, and examine differences between plots in greater detail, hierarchical joining method was used to generate "tree" diagrams. (In this context, the word "tree" is used as the artificial drawing of lines between related items). These diagrams show the linkage of each plot or group of plots as a joining of branches in a tree. Each branch represents a further clustering of the plots into subsets, with the ends of the branches leading to individual plots. Figure 9 shows the tree diagram for the Deciduous Forest Region. Figure 10 shows the tree diagram for the plots in the Great Lakes - St. Lawrence Forest Region. Plot numbers and the K-means cluster number (see Table 13) are indicated to the left of the tree diagrams. At certain branches in the two diagrams, subsets of plots are discriminated which contain plots from only a single K-means cluster. In other words, the tree diagrams confirm the K-means groupings. Further branches in the diagrams suggest possible subdivisions within the K-means groups, down to individual plots. Further subdivisions would, however, not necessarily be meaningful statistically, i.e. with respect to differences between groups versus within groups.

Detailed ANOVAR of the 6 plot groups formed by the K-means clustering was conducted to determine significant differences between the groups with respect to decline index. Table 14 shows the results of the main ANOVAR between these groups. The ANOVAR was significant at the 99.9%

probability level, indicating differences in mean regional decline index values between some plot groups. ANOVAR were also conducted between each pair of groups, to determine the "between-group" differences in more detail. Group 6 was not included in this analysis since it contained only 1 plot. Table 15 summarizes the results of these "contrast" analyses.

There are 3 groups of plots which are significantly different with respect to decline index: Cluster Group 1 ("low" mean decline index of 11.4), Cluster Groups 2,3 and 5 ("intermediate" decline index of 15.3) and Cluster Group 4 ("high" mean decline index of 21.8). Table 16 summarizes descriptive statistics for the 6 cluster groups for decline index, DBH and age. The results show that the plots in the three significantly different groupings encompass similar ranges of stand age and DBH.

Table 17 summarizes mean values for the decline attributes and decline indices for Groups 1 to 5. These figures represent original mean values (not transformed). Although Groups 2,3 and 5 are not significantly different with respect to decline index, they are different with respect to other decline attributes. For example, Group 2 shows higher average slight chlorosis, Group 3 shows higher strong chlorosis, and Group 5 shows higher percent dwarfed leaves. This may indicate that the agents contributing to decline are different between groups.

The locations of the Hardwood Decline study plots in each cluster group are illustrated in Figure 11. The 6 groups formed through detailed analyses confirm the visual geographic patterns observed from Figures 6,7 and 8. Group 1 (low decline) occurs mostly in a band through Central Ontario, centered on the Owen Sound, Wingham, Huronia, Maple, Cambridge, Lindsay, Napanee and Tweed Districts; plus several Northern Ontario plots including some in the Blind River District, one in Sault Ste. Marie and one in Thunder Bay.

Areas of intermediate to high decline (Groups 2,3 and 5) occur in Southern Ontario, mostly along the shores of Lake Erie, Lake Ontario (in the Toronto-Hamilton area), and the southeastern shore of Lake Huron. Another

zone is centered on the Muskoka area and Northeastern Ontario, including the Minden, Bracebridge, Algonquin Park, North Bay, Parry Sound, Sudbury and Espanola Districts. Group 6 (severe decline) occurs as one plot in each of the Owen Sound, Blind River and Thunder Bay Districts. Decline attributes in the Northern Districts of Thunder Bay, Sault Ste. Marie, Bline River and Espanola are highly variable. The cluster groupings show no obvious patterns in these areas. For example, the Blind River and Thunder Bay District have survey plots in both the low and high decline groups.

DISCUSSION AND CONCLUSIONS

Although trees in an advanced stage of decline were observed within individual plots throughout the study area, the distribution of average decline index values for hardwoods shows distinct geographic patterns. A band of low decline stretched through the South Central part of the province from the east shore of Lake Huron south of Georgian Bay, adjacent to the north shore of Lake Ontario and east to Cornwall. The lowest decline values occur in the middle part of this band, centered on the Lindsay and Maple Districts. Decline indices tend to be higher in the northern end of the hardwood forest range and in the Southwestern portion of the province. The distinct geographic decline pattern identified by this survey was confirmed by two different statistical tests of the data (least significant difference of forest section mean decline indices and K means cluster analysis of individual plot decline indices). These data confirm casual observations that hardwood decline is occurring in Ontario but that it is a scattered and isolated phenomenon. The authors have travelled extensively in the hardwood forest zone of NE North American and have observed the characteristics of hardwood decline first hand. By comparison, the severity and extent of decline in Ontario is much less than that in the Eastern Townships of Quebec. In fact, the vast majority of Ontario's hardwood forest appears, at least visually, to be quite healthy. Even the areas identified as high decline in Ontario, i.e. the Southwest and parts of the north, are not experiencing serious

regional forest mortality; rather the plots in these areas are relatively less healthy or in relatively poorer condition compared to those in the central part of the province which were identified as the healthiest.

Southwestern Ontario has the lowest rainfall pH (< 4.2) and the highest atmospheric deposition of pollutants in the province, summarized as follows:

	Wet Deposition	Dry Deposition
Sulfate	> 35 kg/ha/yr	> 16 kg/ha/yr
Nitrate	> 5 kg/ha/yr	> 3 kg/ha/yr
Lead	> 60 g/ha/yr	> 50 g/ha/yr

In addition to low pH rainfall and high deposition the southwest also experiences mean annual growing season daylight ozone concentrations which exceed 50 parts per billion.

In the northern part of the province, the distribution of decline indices do not correlate with atmospheric deposition. However, the soil over large areas of the north is sensitive to acidification by atmospheric pollutants and may, therefore, be a predispositional factor to decline at some sites.

Since one would expect better tree condition in the south where soil and climatic conditions are more favourable, the higher decline indices occurring there suggests that a relationship may exist between hardwood decline and high levels of atmospheric deposition of one or a combination of different pollutants or forest mismanagement.

The incidence of tree diseases, insect activity and other quality defects such as open wounds and frost cracks was high throughout the province for most of the hardwood species studied. Sugar maple for example, averaged one or more defect for every tree assessed. This study was restricted to 'natural forests', which excluded stands managed for syrup production, plantations and stands currently in a scheduled harvest cycle. In reality, however, there are virtually no

completely undisturbed hardwood stands remaining in the province. Most stands have been high-graded for lumber or veneer wood at least once, and often several times. Until recently, long-term stand management, in most regions, has been forfeited for short-term economic gain. This is particularly true in many privately-owned woodlots in the rural southwest. As a result, the quality of the hardwood resource has declined substantially over the last century. These poorer quality trees are may be more susceptible to additional environmental stress factors. The introduction of selection forestry in tolerant hardwoods, particularly in the crown forest, should (with time) result in a better hardwood resource.

The survey results indicate that several other species in addition to sugar maple within the Great Lakes-St. Lawrence and Deciduous Forest Regions show evidence of dieback and decline. These include red oak, black cherry, red maple, white and yellow birch, white ash, basswood and beech.

This study was not intended to establish the cause of tree decline encountered at various locations throughout Ontario. Forest decline is rarely "caused" by single or simple factors. More often, decline is the result of numerous factors which react cumulatively or synergistically on the forest ecosystem. Although air pollutants cannot be ignored as contributing factors to hardwood forest decline in Ontario, especially in areas where the deposition is highest and the soil is most sensitive, a host of equally damaging pathological and stand maintenance factors have not been explored in this study.

This study was intended to present a "snapshot in time" of the condition of Ontario's hardwood forest. Although the survey plots were carefully chosen to be representative of their area, they are still a very small sampling of a very large and very diverse forest resource. None-the-less, these baseline plots, established as permanent

observation plots, will yield valuable data when they are evaluated again in the future. In this way, both a spacial and temporal picture of hardwood tree condition in Ontario can be developed. Using the decline index methodology researchers can determine, within established limits of accuracy, if the condition of the hardwood forest is improving or deteriorating and where in the province the change has occurred.

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TABLE 1: Summary of general location information for Hardwood Decline Survey plots.

Plot Number	Forest Region	Forest Sector	Township	Lot	Concession	MNR District	FRI Stand	NTS 1:50000 map number	UTM Coordinates	Air Photo Number
A-001	GLSL	4B	SOUTH HINSWORTH	n/a	n/a	NORTH BAY	438	31E/14 SOUTH RIVER	17T 628200E 5093900N	n/a
A-002	GLSL	4B	BETHUNE	n/a	n/a	BRACEBRIDGE	243	31E/11 BURK'S FALLS	17T 646200E 5048250N	n/a
A-003	GLSL	4B	STEWART	n/a	n/a	NORTH BAY	81	31L/11 TEMISCAMING	17T 620200E 5155050N	77-4623-100
A-004	GLSL	4B	MERRICK	n/a	n/a	NORTH BAY	83	31L/6 NORTH BAY	17T 616000E 5147250N	77-4620-65-188
A-005	GLSL	4B	BUTT	n/a	n/a	BRACEBRIDGE	70	31E/11 BURK'S FALLS	17T 650200E 5065500N	n/a
A-006	GLSL	2	HAWKSBURY	15	I	CORNWALL	n/a	31G/9 LACHUTE	18T 542300E 5045000N	78-4539-192-104
A-007	GLSL	2	HAWKSBURY	6	I	CORNWALL	n/a	31G/9 LACHUTE	18T 545500E 5044300N	78-4539-192-195
A-008	GLSL	2	CHARLOTTENBURGH	2	I	CORNWALL	n/a	31G/2 & 31B/15 CORNWALL	18T 533400E 4993650N	78-4509-113-135
A-009	GLSL	4B	ROSS	n/a	n/a	PEMBROKE	47	31F/10 COBDEN	18T 363250E 5060000N	76-4529-10-253
A-010	GLSL	2	MARLBOROUGH	24	X	CARLETON PLACE	n/a	31G/4 KEMPTVILLE	18T 425850E 4990300N	78-4506-109-61
A-011	GLSL	2	LANARK	6	IX	CARLETON PLACE	n/a	31F/1 CARLETON PLACE	18T 397500E 4993100N	n/a
A-012	GLSL	2	OXFORD	2	VII	BROCKVILLE	n/a	31B/13 MERRICKVILLE	18T 448400E 4970250N	n/a
A-013	GLSL	10	DAUMONT	n/a	n/a	SAULT STE. MARIE	289	41J/13 RANGER LAKE	17T 279850E 5185500N	81-4633-39-40
A-014	GLSL	2	OSNABRUCK	37	V	CORNWALL	n/a	31G/3 WINCHESTER	18T 491400E 4985900N	78-4501-155-182
A-015	GLSL	10	LABONTE	n/a	n/a	WAWA	216	41N/7 AGAWA BAY	16T 685250E 5246300N	n/a
A-016	GLSL	1	CARLYLE	n/a	n/a	SUDBURY	83	41I/3 LAKE PANACHE	17T 478200E 5100000N	n/a
A-017	GLSL	4D	CHRISTIE	n/a	n/a	PARRY SOUND	113	31E/5 ORRVILLE	17T 595000E 5275000N	77-4517-34-35
A-018	GLSL	4D	MONTEITH	n/a	n/a	PARRY SOUND	100	31E/5 ORRVILLE	17T 609500E 5325000N	77-4519-46-53
A-019	GLSL	1	ESSA	27	VIII	HURONIA	n/a	31D/5 BARRIE	17T 595975E 4907150N	78-4422-10-107
A-020	GLSL	1	MULMUR	2	I	HURONIA	n/a	41A/1 DUNDALK	17T 568900E 4883400N	66-4403-102-43
A-021	GLSL	4B	MULMUR	12	III	HURONIA	n/a	41A/1 DUNDALK	17T 565650E 4889100N	66-4403-102-44
A-022	GLSL	4B	VESPRA	9	VI	HURONIA	n/a	31D/5 BARRIE	17T 597500E 4922000N	n/a
A-023	GLSL	4B	MEDONTE	45	II	HURONIA	n/a	31D/12 ELMVALE	17T 601650E 4935300N	n/a
A-024	GLSL	4B	MEDONTE	45	II	HURONIA	n/a	31D/12 ELMVALE	17T 601450E 4935050N	n/a
A-025	GLSL	4B	TINY	3	XVIII	HURONIA	n/a	31D/13 PENATANGUISHENE	17T 580700E 4965350N	78-4459-5-220
A-026	GLSL	4E	MASON	n/a	n/a	SUDBURY	10	41I/2 DELAMERE	17T 538450E 5103000N	n/a
A-027	GLSL	1	KILLARNEY	n/a	n/a	SUDBURY	147	41I/13 LAKE PANACHE	17T 476325E 5099375N	n/a

TABLE 1 (continued).

Plot Number	Forest Region	Forest Sector	Township	Lot	Concession	MNR District	FRI Stand	NTS 1:50000 map number	UTM Coordinates	Air Photo Number
A-028	GLSL	4E	FAIRBANK	n/a	n/a	SUDBURY	99	41I/6 COPPERCLIFF	17T 467850E 5144750N	n/a
A-029	GLSL	4E	TRILL	n/a	n/a	SUDBURY	41	41I/12 CARTIER	17T 459250E 5150250N	n/a
A-030	GLSL	4E	GOUGH	n/a	n/a	ESPANOLA	105	41I/5 ESPANOLA	17T 427250E 5129750N	n/a
A-031	GLSL	4E	CADEAU	n/a	n/a	ESPANOLA	305	41J/8 WISKEY LAKE	17T 408070E 5130010N	n/a
A-032	GLSL	10	SCARFE	n/a	n/a	BLIND RIVER	76	41J/6 IRON BRIDGE	17T 343000E 5130750N	81-4613-02-59
A-033	GLSL	10	SCARFE	n/a	n/a	BLIND RIVER	55	41J/6 IRON BRIDGE	17T 341250E 5131000N	81-4613-02-59
A-034	GLSL	10	GLADSTONE	n/a	n/a	BLIND RIVER	92	41J/6 IRON BRIDGE	17T 322750E 5131650N	81-4613-02-47
A-035	GLSL	10	WELLS	n/a	n/a	BLIND RIVER	198	41J/6 IRON BRIDGE	17T 312250E 5139250N	81-4616-03-37
A-036	GLSL	10	MACK	n/a	n/a	BLIND RIVER	59	41J/7 ELLIOT LAKE	17T 350900E 5132150N	81-4614-20-116
A-037	GLSL	10	ABERDEEN	n/a	n/a	SAULT STE. MARIE	30	41J/12 ECHO LAKE	17T 279000E 5154600N	81-4622-36-37
A-038	GLSL	10	HILTON	n/a	n/a	SAULT STE. MARIE	14	41J/4 ST. JOSEPH ISLAND	17T 273250E 5124500N	81-4611-05-06
A-039	GLSL	10	WISHART	n/a	n/a	SAULT STE. MARIE	10	41N/1 BATCHEWANA	16T 696500E 5213800N	81-4702-19-20
A-040	GLSL	10	FISHER	n/a	n/a	SAULT STE. MARIE	24	41K/15 PANCAKE BAY	16T 688900E 5204500N	81-4640-04-05
A-041	GLSL	1	NIAGARA ON THE LAKE	49	X	NIAGARA	99	30M/3 & 30M/6 NIAGARA	17T 655700E 4779700N	78-4311-29-279
A-042	GLSL	1	KINLOSS	23	VII	WINGHAM	1	40P/14 WINGHAM	17T 468350E 4869800N	78-4369-215-68
A-043	DCD	1	BERTIE	1	X	NIAGARA	170	30L/14 WELLAND	17T 660500E 4752100N	78-4263-46-164
A-044	DCD	1	TOWN OF MILTON	14	III	CAMBRIDGE	n/a	30M/5 HAMILTON	17T 584650E 4811100N	n/a
A-045	DCD	1	NASSAGAWEYA	6	V	CAMBRIDGE	11	30M/5 BURLINGTON	17T 583250E 4816450N	n/a
A-046	DCD	1	NORFOLK	3	VIII	SIMCOE	7	40I/10 PORT BURWELL	17T 531825E 4725450N	78-4248-211-182
A-047	DCD	1	MALAHIDE	4	V	AYLMER	7	40I/11 PORT STANLEY	17T 498600E 4731400N	78-4251-203-134
A-048	DCD	1	NORWICH	27	IX	SIMCOE	2	40I/15 TILLSONBURG	17T 523600E 4749600N	78-4263-180-145
A-049	DCD	1	BLANDFORD	5	I	AYLMER	n/a	40P/2 WOODSTOCK	17T 528600E 4777020N	78-4311-233-258
A-050	DCD	1	S.W. OXFORD	7	III	AYLMER	n/a	40P/2 WOODSTOCK	17T 518100E 4667700N	78-4305-184-207
A-051	DCD	1	BOSANQUET	48	VI	CHATHAM	2	40P/4 PARKHILL	17T 424700E 4781200N	78-4328-42-181
A-052	DCD	1	ESSA	27	VIII	HURONIA	n/a	31D/5 BARRIE	17T 596800E 4907500N	78-4422-10-106
A-053	DCD	1	ONEIDA	n/a	V	NIAGARA	64	30M/4 HAMILTON/GRIMSBY	17T 588450E 4762375N	78-4302-117-31
A-054	GLSL	4C	REAR OF YOUNG & ESC	21	IX	BROCKVILLE	n/a	31B/12 BROCKVILLE	18T 421850E 4940950N	n/a

TABLE 1 (continued).

Plot Number	Forest Region	Forest Sector	Township	Lot	Concession	MNR District	FRI Stand	NTS 1:50000 map number	UTM Coordinates		Air Photo Number
A-055	DCD	1	LINCOLN	14	VII	NIAGARA	112	30M/3 & 30M/6 NIAGARA	17T 625150E	4775750N	78-4359-29-360
A-056	DCD	1	WILMOT	n/a	NBR	CAMBRIDGE	n/a	40P/7 STRATFORD	17T 530100E	4804700N	n/a
A-057	DCD	1	TOWN OF WHITCHURCH-	22	V	MAPLE	n/a	31D/3 NEWMARKET	17T 632000E	4771500N	n/a
A-058	DCD	1	LINCOLN	21	n/a	NIAGARA	147	30M/3 & 30M/6 NIAGARA	17T 622350E	4774000N	78-4309-29-350
A-059	DCD	1	HAMILTON	5	I	LINDSAY	n/a	30M/16 PORT HOPE	17T 731500E	4875000N	78-4369-50-152
A-060	GLSL	1	CLARKE	21	VIII	LINDSAY	n/a	31D/2 SCUGOG	17T 691800E	4880750N	n/a
A-061	GLSL	4C	CARDIFF	n/a	n/a	BANCROFT	609	31D/16 GOODERHAM	18T 731675E	4978250N	77-4438-16-14
A-062	GLSL	4C	McCLURE	5	XIII	BANCROFT	101	31E/8 WHITNEY	17T 733250E	5023650N	77-4514-53-208
A-063	GLSL	4D	CAVENDISH	n/a	n/a	MINDEN	394	31D/9 BURLEIGH FALLS	17T 714000E	4956950N	77-4431-13-7
A-064	GLSL	4D	GLAMORGEN	18	XIV	MINDEN	112	31D/16 GOODERHAM	17T 700650E	4982200N	77-4440-32-121
A-065	GLSL	4D	STANHOPE	17	VII	MINDEN	209	31E/2 HALIBURTON	17T 679100E	4997300N	77-4507-36-233
A-066	GLSL	4D	HINDON	29	X	MINDEN	153	31E/2 HALIBURTON	17T 659800E	4991900N	77-4502-34-98
A-067	GLSL	4D	SHERBOURNE	n/a	n/a	MINDEN	162	31E/2 HALIBURTON	17T 666600E	5022000N	77-4505-36-177
A-068	DCD	1	WARWICK	29	II	CHATHAM	n/a	40P/4 PARKHILL	17T 434650E	4763020N	78-4302-251-113
A-069	DCD	1	ZARE	31	VII	CHATHAM	n/a	40I/12 BOTHWELL	17T 426150E	4731550N	78-4253-250-98
A-070	DCD	1	EAST WILLIAMS	3	XX	AYLMER	n/a	40P/4 PARKHILL	17T 447650E	4778650N	78-4312-234-57
A-071	GLSL	4D	GEORGIAN BAY	3	VIII	PARRY SOUND	Ind. Res.	31E/4 LAKE JOSEPH	17T 598550E	4986100N	77-4502-34-56
A-072	GLSL	1	BEXLEY	n/a	Long Point	LINDSAY	n/a	31D/10 FENELON FALLS	17T 669700E	4936250N	78-4439-17-492
A-073	GLSL	1	ASPHODEL	9	III	LINDSAY	n/a	31D/8 PETERBOROUGH	17T 736000E	4911600N	78-4420-8-368
A-074	GLSL	1	SCUGOG	14	XI	LINDSAY	n/a	31D/3 NEWMARKET	17T 659400E	4891700N	78-4412-67-202
A-075	DCD	1	KING	20	VI	MAPLE	n/a	30M/13 BOLTON	17T 611800E	4869000N	n/a
A-076	GLSL	1	COLBURNE	9	II	WINGHAM	Morris Tr	40P/12 GODERICH	17T 448450E	4840550N	78-4351-268-70
A-077	GLSL	1	MORRIS	26	VIII	WINGHAM	n/a	40P/11 SEAFORTH	17T 476150E	4839900N	78-4350-268-127
A-078	GLSL	1	CULROSS	25	VI	WINGHAM	n/a	40P/14 WINGHAM	17T 473200E	4870150N	n/a
A-079	GLSL	4C	ANGLESEA	n/a	n/a	TWEED	217	31C/14 MAZINAW LAKE	18t 321800e	4974500n	78-4463-78-24
A-080	GLSL	4C	EFFINGHAM	n/a	n/a	TWEED	265	31F/3 DENBIGH	18T 315400E	4986300N	78-4501-154-168
A-081	GLSL	4C	SOUTH CANONTO	n/a	n/a	TWEED	644	31F/2 CLYDE FORKS	18T 352350E	4988850N	78-4503-154-186

TABLE 1 (continued).

Plot Number	Forest Region	Forest Sector	Township	Lot	Concession	MNR District	FRI Stand	NTS 1:50000 map number	UTM Coordinates		Air Photo Number
A-082	GLSL	2	HALLOWELL	n/a	n/a	NAPANEE	P.P.Res.	30N/14 WELLINGTON	18T 318500E	4863500N	78-4363-12-200
A-083	GLSL	2	BEDFORD	n/a	n/a	NAPANEE	P.P.Res.	31C/10 TICHBORNE	18T 379050e	4936100N	n/a
A-084	GLSL	1	COLLINGWOOD	7	X	OWEN SOUND	492	41A/8 COLLINGWOOD	17T 544800E	4918100N	n/a
A-085	GLSL	1	ST. VINCENT	27	XII	OWEN SOUND	1	41A/10 OWEN SOUND	17T 521700E	4943300N	n/a
A-086	GLSL	2	SOUTH BURGESS	5	II	BROCKVILLE	269	31C/16 PERTH	18T 406700E	4958300N	n/a
A-087	GLSL	1	SAUGEEN	11	IV	OWEN SOUND	n/a	41A/6 CHESLEY	17T 475050E	4911000N	n/a
A-088	GLSL	1	SAUGEEN	36	IX	OWEN SOUND	235	41A/6 CHESLEY	17T 463000E	4916700N	n/a
A-089	GLSL	4D	McKENZIE	29	VII	PARRY SOUND	n/a	41H/9 POINTE AU BARIL S	17T 574550E	5062650N	77-4530-86-34
A-090	GLSL	4D	FERRIE	25	VII	PARRY SOUND	222	31E/13 GOLDEN VALLEY	17T 590850E	5068350N	77-4532-43-142
A-091	GLSL	4D	CHAPMAN	n/a	n/a	PARRY SOUND	247	31E/12 MAGNETAWAN	17T 606050E	5057850N	77-4528-86-318
A-092	GLSL	4D	LOUNT	25	XI	PARRY SOUND	4	31E/13 GOLDEN VALLEY	17T 600550E	5078850N	77-4536-57-100
A-093	GLSL	4E	SANDFIELD	26	X	ESPANOLA	342	41G/16 KAGAWONG	17T 414700E	5068200N	73-4532-9-229
A-094	GLSL	4E	ALLAN	19	X	ESPANOLA	246	41G/16 KAGAWONG	17T 393900E	5084650N	73-4538-2-120
A-095	GLSL	4E	ROBINSON	28	XI	ESPANOLA	208	41G/15 SILVER WATER	17T 353300E	5083400N	73-4537-8-50
A-096	GLSL	4B	FINLAKSON	n/a	n/a	ALGONQUIN PARK	332	31E/7 KAWAGAMA LAKE	17T 670150E	5033900N	n/a
A-097	GLSL	4B	PECK	n/a	n/a	ALGONQUIN PARK	272	31E/10 TOM THOMSON LAKE	17T 681400E	5045600N	n/a
A-098	GLSL	4B	SPROULE	n/a	n/a	ALGONQUIN PARK	821	31E/9 OPEONGO LAKE	17T 710650E	5051700N	n/a
A-099	GLSL	4B	DICKSON	n/a	n/a	ALGONQUIN PARK	n/a	31E/16 LAKE LAVIELLE	17T 707400E	5077300N	n/a
A-100	GLSL	4C	JONES	n/a	n/a	PEMBROKE	228	31F/5 BARRY'S BAY	18T 281200E	5036650N	76-4520-7-118
A-101	GLSL	4E	NIPISSING	n/a	n/a	NORTH BAY	n/a	31L/4 NIPISSING	17T 610700E	5105550N	77-4604-81-122
A-102	GLSL	1	ST. EDMUNDS	20	VI	OWEN SOUND	542	41H/3 DYER'S BAY	17T 462170E	5007150N	n/a
A-103	GLSL	1	EASTNOR	n/a	XI	OWEN SOUND	n/a	41A/14 CAPE CROCKER	17T 488000E	4974000N	n/a
A-104	GLSL	4E	PAPINEAK	22	XII	NORTH BAY	n/a	31L/7 MATTAWA	17T 673500E	5127500N	77-4608-69-146
A-105	GLSL	1	KEPPEL	n/a	XI	OWEN SOUND	n/a	41A/14 CAPE CROCKER	17T 492450E	4962400N	n/a
A-106	GLSL	4E	TRUMAN	n/a	n/a	ESPANOLA	Unsurveye	41I/4 WHITEFISH FALLS	17T 456200E	5115650N	n/a
A-107	GLSL	4E	McKINNON	n/a	n/a	ESPANOLA	Unsurveye	41I/4 WHITEFISH FALLS	17T 430550E	5109450N	n/a
A-108	GLSL	11	BLAKE	n/a	n/a	THUNDER BAY	n/a	52A/6 THUNDER BAY	16U 322650E	5349500N	n/a
A-109	GLSL	11	BLAKE	n/a	n/a	THUNDER BAY	n/a	52A/6 THUNDER BAY	16U 321850E	5350600N	n/a
A-110	GLSL	11	PARDEE	n/a	n/a	THUNDER BAY	n/a	52A/4 PIDGEON RIVER	16U 307400E	5326300N	n/a

TABLE 2: Summary of Field Soils Data for the Hardwood Decline Plots.

Plot No.	Date	Forest Region	Forest Section	MNR District	Depth (cm) to Bedrock	Depth (cm) to Carb.	Internal Drainage	Moisture Regime	A Horizon Texture	A Horizon Thickness	B Horizon Texture	B Horizon Thickness	C Horizon Texture	Slope Percent	Slope Type	Position On Slope	Gravel (depth)	Rockiness	Stoniness
A-001	8/11/85	GL	4E	NORTH BAY	200	200	well	1	SL	0	SL	0	rock	0	N/A	upper	none	very	moderate
A-002	8/17/85	GL	4B	BRACEBRIDGE	80	200	well	2	SL	10	SL	30	SL	0	N/A	upper	none	slight	slight
A-003	8/16/85	GL	4B	NORTH BAY	200	200	well	2	L	8	L	39	L	0	N/A	upper	80-120	slight	slight
A-004	8/19/85	GL	4B	NORTH BAY	51	200	well	2	S	11	SL	27	SL	0	N/A	upper	none	moderate	moderate
A-005	8/21/85	GL	4B	BRACEBRIDGE	35	200	well	2	L	13	L	22	N/A	0	N/A	upper	none	non	non
A-006	9/17/85	GL	2	CORNWALL	65	200	well	2	fSL	7	fSL	23	fSL		N/A	upper	none	non	non
A-007	9/16/85	GL	2	CORNWALL	30	200	well	2	fSL	5	fSL	21	N/A		N/A	flat	0-30	non	moderate
A-008	9/14/85	GL	2	CORNWALL	30	200	well	2	CL	7	CL	11	CL		N/A	flat	none	non	non
A-009	8/27/85	GL	4B	PEMBROKE	200	200	rapid	1	LfS	1	LS	9	fS	0	N/A	flat	30-120	moderate	slight
A-010	8/20/85	GL	2	CARLETON PLACE	200	200	rapid	1	LS	3	LS	12	LS	0	N/A	flat	none	moderate	moderate
A-011	8/29/85	GL	2	CARLETON PLACE	200	200	well	2	SL	9	SL	9	SL	0	N/A	crest	33-120	non	moderate
A-012	8/29/85	GL	2	BROCKVILLE	53	200	rapid	1	LfS	10	LfS	10	LfS	0	N/A	middle	none	non	non
A-013	8/07/85	GL	10	SAULT STE. MARIE	200	200	rapid	1	LS	5	LS	25	LS	0	N/A	flat	none	non	slight
A-014	9/15/85	GL	2	CORNWALL	55	200	well	2	SL	8	SL	35	SL		N/A	flat	0-55	very	moderate
A-015	8/09/85	GL	10	WAWA	30	200	well	2	CL	6	L	24	N/A	0	N/A	crest	none	non	non
A-016	9/27/85	GL	4D	SUDBURY	200	200	well	2	SiL	3	SiL	27	SiL		N/A	lower	none	slight	slight
A-017	9/27/85	GL	4D	PARRY SOUND	55	200	well	2	fSL	14	fSL	27	fSL		N/A	upper	0-55	moderate	non
A-018	9/28/85	GL	4D	PARRY SOUND	55	200	well	2	fSL	13	fSL	25	fSL		N/A	flat	0-55	slight	non
A-019	9/25/85	GL	1	HURONIA	75	200	rapid	1	LfS	5	LfS	42	LfS		N/A	flat	none	non	non
A-020	9/24/85	GL	1	HURONIA	35	200	well	2	fSL	15	L	10	L		N/A	middle	none	slight	slight
A-021	8/23/85	GL	4B	HURONIA	40	200	well	2	L	9	L	15	L	0	N/A	middle	none	very	moderate
A-022	8/24/85	GL	4B	HURONIA	50	200	well	2	mSL	10	mS	40	N/A	0	N/A	middle	none	slight	slight
A-023	8/25/85	GL	4B	HURONIA	200	200	well	2	mS	4	N/A	12	N/A	0	N/A	flat	none	non	non
A-024	8/24/85	GL	4B	HURONIA	60	200	well	2	mS	15	mS	45	N/A	0	N/A	lower	none	non	non
A-025	8/25/85	GL	4B	HURONIA	35	200	well	2	mSL	10	mSL	25	N/A	0	N/A	middle	none	slight	slight
A-026	8/29/85	GL	4E	SUDBURY	200	200	mod.well	2	SiC	3	SiC	17	SiC	0	N/A	flat	none	non	non
A-027	8/27/85	GL	1	SUDBURY	200	200	well	2	Si	5	Si	40	Si	0	N/A	flat	none	non	non

TABLE 2 (continued).

Plot No.	Date	Forest Region	Forest Section	MNR District	Depth (cm) to Bedrock	Depth (cm) to Carb.	Internal Drainage	Moisture Regime	A Horizon Texture	A Horizon Thickness	B Horizon Texture	B Horizon Thickness	C Horizon Texture	Slope Percent	Slope Type	Position On Slope	Gravel (depth)	Rockiness	Stoniness
A-028	8/28/85	GL	4E	SUDBURY	20	200	well	2	Si	3	Si	12	N/A	0	N/A	middle	none	moderate	moderate
A-029	8/28/85	GL	4E	SUDBURY	40	200	well	2	vfSL	3	vfSL	27	vfSL	0	N/A	middle	none	exceed	exceed
A-030	8/18/85	GL	4E	ESPANOLA	200	200	mod.well	3	SiL	4	SifS	26	CL	0	N/A	lower	none	non	non
A-031	8/18/85	GL	4E	ESPANOLA	20	200	well	2	LfS	7	LfS	13	N/A	0	N/A	crest	none	exceed	non
A-032	8/16/85	GL	10	BLIND RIVER	10	200	well	2	LmS	8	LmS	1	N/A	0	N/A	middle	none	slight	slight
A-033	8/17/85	GL	10	BLIND RIVER	20	200	rapid	1	LmS	6	LfS	14	N/A	0	N/A	middle	none	slight	non
A-034	8/15/85	GL	10	BLIND RIVER	55	200	well	2	fLS	3	LfS	52	N/A	0	N/A	middle	none	moderate	moderate
A-035	8/17/85	GL	10	BLIND RIVER	70	200	well	2	vfSL	5	vfSL	45	L	0	N/A	upper	none	slight	slight
A-036	8/15/85	GL	10	BLIND RIVER	30	200	rapid	0	LmS	7	LmS	23	N/A	0	N/A	flat	none	non	non
A-037	8/14/85	GL	10	SAULT STE. MARIE	50	200	rapid	1	fLS	6	LfS	21	fLS	0	N/A	crest	none	slight	slight
A-038	8/13/85	GL	10	SAULT STE. MARIE	30	200	well	2	mS	15	mS	15	N/A	0	N/A	flat	none	non	non
A-039	8/13/85	GL	10	SAULT STE. MARIE	40	200	well	2	vfSL	10	L	30	N/A	0	N/A	middle	none	slight	slight
A-040	8/14/85	GL	10	SAULT STE. MARIE	70	200	mod.well	3	fSL	6	fSL	35	LS	0	N/A	flat	none	slight	slight
A-041	6/19/86	DC	1	NIAGARA	200	5	imperfect	6	SiCL	13	SiCL	23	SiCL	0	S	middle	0-120	exceed	exceed
A-042	9/19/86	GL	1	WINGHAM	75	200	mod.well	4	L	8	L	60	Sil	50	N/A	flat	none	non	non
A-043	6/18/86	DC	1	NIAGARA	200	0	well	2	GL	8	GL	32	N/A	0	N/A	flat	0-120	exceed	exceed
A-044	6/03/86	DC	1	CAMBRIDGE	200	200	well	2	L	20	fSL	50	fSL	0	S	flat	0-120	excess	excess
A-045	6/02/86	DC	1	CAMBRIDGE	200	200	well	2	L	20	CL	40	N/A	0	S	middle	0-65	excess	excess
A-046	6/11/86	DC	1	SIMCOE	200	80	mod.well	3	L	30	SiL	50	SiL	0	S	flat	none	non	non
A-047	6/12/86	DC	1	AYLMER	200	200	well	2	fSL	20	fSL	80	fSL	30	N/A	N/A	none	non	non
A-048	6/12/86	DC	1	SIMCOE	200	200	imperfect	5	SiL	25	SivfS	42	N/A	0	S	middle	none	non	non
A-049	6/06/86	DC	1	AYLMER	200	85	imperfect	4	L	14	fSL	70	fSL	5	C	toe	none	non	non
A-050	6/04/86	DC	1	AYLMER	200	87	mod.well	3	CL	12	SiL	75	CL	0	S	flat	none	non	non
A-051	6/24/86	DC	1	CHATHAM	200	200	well	2	SL	14	SL	58	SCL	0	S	flat	none	non	non
A-052	7/07/86	DC	1	SIMCOE	200	200	well	2	LvfS	8	LvfS	20	vfS	0	C	crest	none	non	non
A-053	6/30/86	DC	1	NIAGARA	200	38	mod.well	2	CL	20	C	18	SiC	0	S	crest	none	non	non
A-054	7/13/86	GL	2	BROCKVILLE	65	8	well	2	fSL	7	L	58	N/A	1	S	middle	0	moderate	moderate

TABLE 2 (continued).

Plot No.	Date	Forest Region	Forest Section	MNR District	Depth (cm) to Bedrock	Depth (cm) to Carb.	Internal Drainage	Moisture Regime	A Horizon Texture	A Horizon Thickness	B Horizon Texture	B Horizon Thickness	C Horizon Texture	Slope Percent	Slope Type	Position On Slope	Gravel (depth)	Rockiness	Stoniness
A-055	6/17/86	DC	1	NIAGARA	200	75	well	2	SiL	20	SiCL	55	SiCL	0	N/A	flat	none	non	non
A-056	6/16/86	DC	1	CAMBRIDGE	200	200	mod.well	4	fSL	25	fSL	50	LfS	0	S	flat	none	non	slight
A-057	6/11/86	DC	1	MAPLE	200	200	well	2	SifS	5	vfSL	12	vfSL	30	S	middle	none	non	non
A-058	9/17/86	DC	1	NIAGARA	100	200	well	2	L	25	L	40	L	3	C	lower	0	exceed	moderate
A-059	6/26/86	DC	1	LINDSAY	90	42	well	2	L	10	fSL	32	LfS	0	S	upper	10	slight	slight
A-060	6/25/86	GL	1	LINDSAY	200	20	well	2	vfSL	20	fSL	25	fS	3	S	middle	20-45	slight	slight
A-061	6/18/86	GL	4C	BANCROFT	80	200	well	3	fSL	8	fSL	50	CL	5	C	middle	none	moderate	moderate
A-062	7/16/86	GL	4C	BANCROFT	60	200	rapid	0	LS	8	LfS	50	N/A	50	S	middle	none	non	moderate
A-063	6/15/86	GL	4D	MINDEN	50	200	well	2	N/A	12	fSL	28	vfSL	5	C	depression	none	non	slight
A-064	6/19/86	GL	4D	MINDEN	90	200	mod.well	3	LvfS	15	SivfS	40	SifS	5	C	upper	none	slight	slight
A-065	7/16/86	GL	4D	MINDEN	68	200	well	1	LfS	10	LfS	55	N/A	20	C	upper	0-15	slight	slight
A-066	6/19/86	GL	4D	MINDEN	60	200	well	2	LvfS	20	LvfS	40	N/A	20	C	upper	none	moderate	moderate
A-067	8/06/86	GL	4D	MINDEN	200	200	well	2	vfSL	15	vfSL	55	SiL	0	C	lower	33-120	moderate	slight
A-068	6/25/86	DC	1	CHATHAM	200	50	imperfect	5	CL	12	CL	38	CL	0	S	flat	none	non	non
A-069	6/26/86	DC	1	CHATHAM	200	85	well	2	LvfS	10	LvfS	90	N/A	0	S	flat	none	non	non
A-070	7/03/86	DC	1	ATLMER	200	45	rapid	0	LmS	15	LmS	40	Lms	0	S	crest	0-120	slight	moderate
A-071	8/18/86	GL	4D	PARRY SOUND	200	42	mod.well	4	vfS	6	vfS	42	N/A	20	S	middle	0-23	non	very
A-072	6/23/86	GL	1	LINDSAY	200	10	well	2	L	10	L	20	fSL	0	S	lower	none	slight	slight
A-073	2/18/86	GL	1	LINDSAY	200	200	well	2	vfSL	20	LvfS	40	LvfS	0	N/A	N/A	none	non	non
A-074	6/24/86	GL	1	LINDSAY	80	65	well	2	L	18	L	22	CL	3	S	upper	65-80	slight	slight
A-075	6/30/86	DC	1	MAPLE	200	110	well	1	SivfS	12	SivfS	80	SivfS	30	C	upper	none	slight	non
A-076	7/02/86	GL	1	WINGHAM	200	20	imperfect	5	SiCL	20	SiC	30	SiC	60	N/A	lower	none	non	slight
A-077	7/18/86	GL	1	WINGHAM	200	25	N/A	2	L	8	vfSL	20	fS	0	C	lower	25-120	slight	slight
A-078	7/28/86	GL	1	WINGHAM	200	200	rapid	0	LmS	10	mS	35	mS	40	C	upper	15-120	non	non
A-079	7/02/86	GL	4C	TWEED	70	200	well	2	vfSL	8	vfSL	15	vfSL	40	S	upper	0-70	non	moderate
A-080	7/01/86	GL	4C	TWEED	90	200	well	2	LvfS	6	LvfS	70	N/A	25	C	upper	25-35	moderate	moderate

TABLE 2 (continued).

Plot No.	Date	Forest Region	Forest Section	MNR District	Depth (cm) to Bedrock	Depth (cm) to Carb.	Internal Drainage	Moisture Regime	A Horizon Texture	A Horizon Thickness	B Horizon Texture	B Horizon Thickness	C Horizon Texture	Slope Percent	Slope Type	Position On Slope	Gravel (depth)	Rockiness	Stoniness
A-081	7/03/86	GL	4C	TWEED	110	200	well	1	LfS	40	LfS	65	N/A	20	S	middle	none	slight	slight
A-082	7/04/86	GL	2	NAPANEE	50	20	well	2	SiC	10	SiC	40	N/A	0	N/A	flat	0-20	non	non
A-083	8/11/86	GL	2	NAPANEE	70	200	mod.well	2	CL	8	SiC	52	N/A	35	S	middle	0-60	moderate	moderate
A-084	7/30/86	GL	1	OWEN SOUND	64	15	well	2	L	8	L	52	N/A	40	S	middle	0-61	moderate	moderate
A-085	7/15/86	GL	1	OWEN SOUND	40	200	mod.well	2	SiC	7	SiC	33	N/A	5	S	lower	none	very	non
A-086	9/24/86	GL	2	BROCKVILLE	45	200	well	2	vfSL	10	vfSL	35	N/A	10	S	middle	0-45	moderate	moderate
A-087	7/16/86	GL	1	OWEN SOUND	200	200	mod.well	3	fSL	18	vfS	58	vfS	0	N/A	N/A	none	slight	slight
A-088	7/15/86	GL	1	OWEN SOUND	200	40	well	2	LvfS	24	vfSL	20	LvfS	0	S	N/A	0-90	non	non
A-089	7/22/86	GL	4D	PARRY SOUND	70	200	well	2	SiL	10	SiL	30	SiL	5	C	middle	35-70	non	slight
A-090	7/22/86	GL	4D	PARRY SOUND	200	200	imperfect	4	SiL	11	SifS	29	fSL	5	C	N/A	none	slight	slight
A-091	7/23/86	GL	4D	PARRY SOUND	200	200	well	2	SiL	15	SiL	22	vfSL	5	C	middle	10-80	moderate	moderate
A-092	8/01/86	GL	4D	PARRY SOUND	55	200	well	1	SifS	15	SivfS	40	N/A	20	S	upper	0-55	slight	sli9ght
A-093	7/22/86	GL	4E	ESPANOLA	25	200	rapid	1	LfS	20	LfS	5	N/A	0	N/A	N/A	0-25	slight	slight
A-094	7/24/86	GL	4E	ESPANOLA	200	200	well	2	SifS	13	SifS	35	N/A	0	N/A	N/A	48-120	moderate	moderate
A-095	7/23/86	GL	4E	ESPANOLA	50	200	well	1	vfS	15	SifS	30	N/A	0	N/A	N/A	0-50	very	very
A-096	8/01/86	GL	4B	ALGONQUINPK	200	200	well	2	L	10	LvfS	50	LfS	10	S	middle	63-100	slight	non
A-097	7/30/86	GL	4B	ALGONQUINPK	100	200	well	2	L	15	vfSL	45	LfS	10	S	middle	60-100	non	non
A-098	7/31/86	GL	4B	ALGONQUINPK	200	200	well	2	fSL	10	fSL	28	LvfS	12	S	upper	0-83	non	non
A-099	8/07/86	GL	4B	ALGONQUINPK	70	200	N/A	2	vfSL	15	SivfS	35	SivfS	0	S	crest	9-70	very	very
A-100	8/08/86	GL	4C	PEMBROKE	52	200	well	2	fSL	8	LvfS	49	N/A	0	C	middle	0-52	very	very
A-101	8/20/86	GL	4E	NORTH BAY	80	200	well	2	L	8	SiL	47	LmS	2	C	upper	0-80	moderate	moderate
A-102	8/13/86	GL	1	OWEN SOUND	200	200	well	2	SL	15	SifL	25	N/A	0	C	flat	0-55	moderate	slight
A-103	8/14/86	GL	1	OWEN SOUND	65	200	well	2	SiL	7	SiL	43	SiCL	5	C	crest	40-65	exceed	exceed
A-104	8/21/86	GL	4E	NORTH BAY	60	200	mod.well	3	vfSL	5	L	30	vfSL	1	S	middle	25-60	moderate	moderate
A-105	8/15/86	GL	1	OWEN SOUND	200	200	well	2	SiCL	10	SiL	36	Si	0	C	flat	none	moderate	moderate
A-106	8/06/86	GL	4E	ESPANOLA	50	200	well	1	LfS	10	LfS	35	N/A	0	N/A	flat	0-50	non	non
A-107	8/07/86	GL	4E	ESPANOLA	200	200	well	2	SimS	5	SimS	28	N/A	20	S	upper	none	non	non
A-108	7/09/86	GL	11	THUNDER BAY	200	200	mod.well	4	L	10	L	40	L	5	S	middle	0-120	non	non
A-109	7/10/86	GL	11	THUNDER BAY											N/A				
A-110	7/11/86	GL	11	THUNDER BAY	200	200	imperfect	5	fSL	10	SCL	40	N/A	20	S	middle	0-120	exceed	exceed

Notes:

1. In the 'Bedrock' (depth to bedrock) and 'Carb.' (depth to free carbonates) fields, a coded value of '200' indicates that no bedrock or free carbonates were encountered.
2. In the Slope Type field, 'S' indicates simple slopes, while 'C' indicates complex topography.

TABLE 3: Summary of general forest stand characteristics of the hardwood decline study plots.

Plot Number	MNR District	DBH (cm)	Height (m)	Breast Height Age	Total Basal Area (m2/ha)	% Crown Closure
A-001	NORTH BAY	16.8	15.6		20.0	75
A-002	BRACEBRIDGE	21.0	20.2	93	34.0	75
A-003	NORTH BAY	21.1	19.9		28.0	75
A-004	NORTH BAY	21.8	17.0		20.0	65
A-005	BRACEBRIDGE	25.9	18.9	113	26.0	
A-006	CORNWALL	32.9	25.3	107	23.2	
A-007	CORNWALL	35.7	26.8	103	25.2	85
A-008	CORNWALL	22.6	19.7	73	22.0	80
A-009	PEMBROKE	22.3	19.1	77	14.0	50
A-010	CARLETON PL	22.7	18.6	82	20.4	
A-011	CARLETON PL	20.8	14.5		24.4	80
A-012	BROCKVILLE	22.6	19.9	93	18.8	65
A-013	SAULTSTMARIE	22.4	16.3	78	18.8	50
A-014	CORNWALL	22.0	19.7	81	19.6	85
A-015	WAWA	23.1	14.6		18.8	50
A-016	SUDBURY	22.4	18.1	93	21.6	90
A-017	PARRY SOUND	17.7	13.2	76	18.8	
A-018	PARRY SOUND	26.2	17.8	82	14.8	
A-019	HURONIA	36.7	27.8	102	26.0	75
A-020	HURONIA	26.8	21.0	85	24.8	90
A-021	HURONIA	26.5	21.2	86	26.4	90
A-022	HURONIA	21.0	19.5	95	25.6	99
A-023	HURONIA	20.7	18.9	102	24.0	95
A-024	HURONIA	25.0	18.7	95	24.0	90
A-025	HURONIA	21.4	20.0		19.6	99
A-026	SUDBURY	20.8	18.9	86	22.0	75
A-027	SUDBURY	23.2	18.8	117	23.6	
A-028	SUDBURY	21.0	18.2	82	24.0	85
A-029	SUDBURY	20.1	18.3	82	24.0	70
A-030	ESPANOLA	26.3	21.8	127	19.6	70
A-031	ESPANOLA	17.8	16.0		18.8	85
A-032	BLIND RIVER	23.2	16.8	87	23.2	80
A-033	BLIND RIVER	24.4	18.1		25.6	85
A-034	BLIND RIVER	24.6	18.7	103	22.0	90
A-035	BLIND RIVER	18.9	14.8	73	19.2	70
A-036	BLIND RIVER	29.5	20.0		26.8	85
A-037	SAULTSTMARIE	27.3	22.3		23.6	65
A-038	SAULTSTMARIE	20.6	18.2		19.6	
A-039	SAULTSTMARIE	22.1	15.4	77	22.4	60
A-040	SAULTSTMARIE	27.3	19.4	76	22.4	90
A-041	NIAGARA	27.3	19.6	63	14.8	85
A-042	WINGHAM	35.1	29.7	102	28.8	85

TABLE 3: (continued).

Plot Number	MNR District	DBH (cm)	Height (m)	Breast Height Age	Total Basal Area (m2/ha)	% Crown Closure
A-043	NIAGARA	29.2	25.8	60	22.8	90
A-044	CAMBRIDGE	28.8	22.9	85	21.6	80
A-045	CAMBRIDGE	26.4	23.8	77	23.2	80
A-046	SIMCOE	30.3	25.6	69	24.0	85
A-047	AYLMER	30.2	25.8	65	22.8	85
A-048	SIMCOE	27.5	25.6	96	27.6	75
A-049	AYLMER	26.0	28.6	71	24.4	85
A-050	AYLMER	31.9	29.5	80	25.6	80
A-051	CHATHAM	26.8	25.2	74	23.2	70
A-052	HURONIA	23.5	24.1	79	30.0	75
A-053	NIAGARA	21.3	20.8	63	20.8	90
A-054	BROCKVILLE	24.9	21.1	100	21.2	60
A-055	NIAGARA	23.4	24.6	60	26.0	90
A-056	CAMBRIDGE	26.2	27.2	67	26.4	80
A-057	MAPLE	26.8	19.8	89	22.0	95
A-058	NIAGARA	25.2	21.1	84	28.0	80
A-059	LINDSAY	23.2	19.6	63	16.0	60
A-060	LINDSAY	24.9	21.3	76	16.0	70
A-061	BANCROFT	25.0	25.5		21.2	65
A-062	BANCROFT	21.3	21.7	67	26.4	95
A-063	MINDEN	23.5	21.1	90	24.0	65
A-064	MINDEN	28.0	23.3		23.2	60
A-065	MINDEN	19.9	17.2	71	26.4	75
A-066	MINDEN	25.9	22.3		15.6	50
A-067	MINDEN	28.8	21.6	87	24.8	65
A-068	CHATHAM	22.2	22.5	63	23.6	85
A-069	CHATHAM	57.7	23.1	60	25.2	70
A-070	AYLMER	26.4	24.7	81	28.4	80
A-071	PARRY SOUND	23.8	19.5	117	32.4	75
A-072	LINDSAY	26.9	21.9		21.2	65
A-073	LINDSAY	30.6	24.8	96	24.8	70
A-074	LINDSAY	26.8	24.7	79	16.8	65
A-075	MAPLE	26.8	24.8	108	24.4	80
A-076	WINGHAM	26.5	26.9	61	34.0	80
A-077	WINGHAM	19.8	19.8	75	30.4	90
A-078	WINGHAM	22.1	22.2	68	28.8	80
A-079	TWEED	24.9	21.3	97	26.8	80
A-080	TWEED	23.0	17.6	94	21.6	60
A-081	TWEED	20.2	19.0	104	30.0	70
A-082	NAPANEE	25.1	21.3	114	26.4	75
A-083	NAPANEE	22.5	20.0	85	18.0	60
A-084	OWEN SOUND	25.7	21.3	100	26.4	85

TABLE 3 **(continued).**

Plot Number	MNR District	DBH (cm)	Height (m)	Breast Height Age	Total Basal Area (m2/ha)	% Crown Closure
A-085	OWEN SOUND	22.2	22.3	63	26.0	70
A-086	BROCKVILLE	24.6	20.8	84	20.0	75
A-087	OWEN SOUND	35.4	28.0	77	29.2	65
A-088	OWEN SOUND	20.2	21.5	73	33.2	85
A-089	PARRY SOUND	19.2	16.9	74	22.8	75
A-090	PARRY SOUND	27.0	20.0	95	25.6	60
A-091	PARRY SOUND	22.6	18.6	68	24.0	65
A-092	PARRY SOUND	25.1	19.9	102	26.4	75
A-093	ESPANOLA	21.3	18.2	67	25.6	60
A-094	ESPANOLA	21.0	18.3	77	24.4	60
A-095	ESPANOLA	26.2	20.2	122	22.0	50
A-096	ALGONQUINPK	30.4	21.0	93	24.4	75
A-097	ALGONQUINPK	25.0	20.8	88	28.0	80
A-098	ALGONQUINPK	20.2	20.6	60	29.6	75
A-099	ALGONQUINPK	25.5	20.3	75	28.8	75
A-100	PEMBROKE	24.0	19.8	83	30.4	80
A-101	NORTH BAY	24.9	23.0	74	25.2	70
A-102	OWEN SOUND	20.3	21.2	75	33.6	85
A-103	OWEN SOUND	23.4	18.1	87	29.2	80
A-104	NORTH BAY	24.6	19.7	82	26.0	75
A-105	OWEN SOUND	21.9	18.7	70	31.2	85
A-106	ESPANOLA	28.0	20.2	133	26.8	75
A-107	ESPANOLA	18.9	17.9	70	20.4	70
A-108	THUNDER BAY	20.7	16.9	78	22.4	80
A-109	THUNDER BAY	27.8	18.9		28.4	65
A-110	THUNDER BAY	19.2	16.8		25.2	50

TABLE 4: Summary of tree quality and decline data for all plots, 1986.

Plot No.	Dead Branches	Slight Chlor	Strong Chlor	Small Leaves	Decline Index	Total Defects	Crown Class
A-001	13.15	15.16	0.77	0.75	15.05	207	4
A-002	14.20	8.05	2.10	0.00	15.45	202	4
A-003	13.80	4.01	0.09	0.00	14.22	172	4
A-004	16.15	4.90	2.39	0.00	16.77	259	4
A-005	8.45	6.15	4.29	0.00	10.10	188	3
A-006	10.55	2.05	2.77	0.00	11.37	184	4
A-007	8.00	5.25	2.51	0.00	9.15	234	3
A-008	12.20	2.40	4.32	0.40	13.44	136	4
A-009	11.85	2.16	12.09	0.00	14.64	97	4
A-010	9.80	3.40	13.69	0.35	13.14	175	4
A-011	15.50	1.90	8.87	0.00	17.53	207	4
A-012	7.45	0.35	7.02	0.00	9.02	144	3
A-013	18.25	9.25	2.72	0.10	19.70	211	4
A-014	9.90	3.40	1.87	0.05	10.66	143	3
A-015	12.86	2.51	3.41	0.10	13.84	145	4
A-016	13.85	7.65	2.41	2.69	15.72	215	4
A-017	20.72	0.60	22.91	0.30	25.32	220	4
A-018	9.55	0.05	1.22	0.60	9.94	237	3
A-019	11.07	0.50	3.45	0.00	11.87	161	4
A-020	13.12	10.20	11.96	0.00	16.48	128	4
A-021	10.40	4.40	2.37	0.30	11.29	187	4
A-022	8.44	2.15	0.08	0.25	8.80	100	3
A-023	11.92	1.45	1.19	0.60	12.47	176	4
A-024	12.71	1.34	13.42	1.14	15.89	132	4
A-025	9.89	0.80	1.22	0.10	10.21	167	3
A-026	14.50	2.65	1.64	0.25	15.16	182	4
A-027	12.60	6.80	3.09	0.50	13.91	259	4
A-028	17.62	0.60	1.09	1.35	18.08	160	4
A-029	20.70	0.35	2.19	0.20	20.99	177	4
A-030	17.25	2.62	0.15	0.00	17.45	291	4
A-031	12.35	1.65	1.10	2.30	13.26	211	4
A-032	12.22	1.03	0.39	0.10	12.24	151	4
A-033	11.36	4.50	2.98	0.50	12.57	197	3
A-034	11.02	0.84	2.19	0.00	11.50	152	4
A-035	13.77	2.28	5.05	1.04	15.21	113	4
A-036	10.60	0.00	0.16	1.70	10.96	186	3
A-037	25.29	18.50	8.85	0.55	28.74	174	4
A-038	17.30	17.90	4.62	0.00	20.11	195	4
A-039	13.47	2.31	4.69	0.35	14.68	100	4
A-040	11.10	0.90	1.02	0.45	11.45	133	3
A-041	20.85	7.46	2.04	0.00	21.86	94	4
A-042	4.55	0.30	8.38	0.00	6.60	138	3
A-043	15.55	0.50	1.00	4.01	16.32	128	4
A-044	13.60	0.00	0.09	1.08	13.84	69	4
A-045	18.60	0.00	0.16	0.20	18.66	151	4
A-046	12.30	0.00	0.44	2.10	12.85	44	3

TABLE 4 (continued).

Plot No.	Dead Branches	Slight Chlor	Strong Chlor	Small Leaves	Decline Index	Total Defects	Crown Class
A-047	14.20	0.50	0.10	3.65	15.01	66	4
A-048	14.40	0.00	0.30	0.00	14.45	60	4
A-049	14.55	0.00	1.90	0.70	15.03	40	4
A-050	18.49	0.00	0.74	0.95	18.77	65	4
A-051	11.90	0.15	0.05	1.82	12.34	105	4
A-052	14.04	0.07	1.00	0.70	14.22	91	4
A-053	10.86	0.00	0.00	0.70	11.03	46	3
A-054	8.87	0.80	0.95	0.06	9.17	74	3
A-055	16.80	0.00	0.53	4.00	17.71	71	4
A-056	15.90	0.10	0.66	0.30	16.09	128	4
A-057	6.28	0.15	0.40	0.00	6.36	32	3
A-058	13.35	6.70	1.99	0.00	14.47	150	4
A-059	8.15	0.06	0.17	0.30	8.23	114	3
A-060	5.80	0.00	0.18	0.00	5.82	69	3
A-061	19.05	0.40	1.07	3.00	19.73	91	4
A-062	8.55	0.00	0.64	0.00	8.66	131	3
A-063	16.65	1.55	2.10	0.90	17.33	76	3
A-064	20.17	0.69	2.41	0.20	20.75	113	4
A-065	15.50	0.10	1.34	0.90	15.91	120	4
A-066	18.40	1.76	0.61	0.00	18.68	121	4
A-067	14.10	0.55	0.31	9.01	16.24	198	4
A-068	16.55	0.10	0.11	5.08	17.55	61	4
A-069	15.25	3.60	1.18	0.55	16.10	78	4
A-070	13.84	0.05	0.05	1.55	14.19	38	4
A-071	13.04	2.70	1.31	1.00	13.81	200	4
A-072	4.70	1.95	1.39	0.00	5.26	18	2
A-073	10.05	0.45	0.46	0.00	10.14	142	3
A-074	4.35	0.06	0.02	0.00	4.36	25	2
A-075	7.26	2.30	0.00	0.00	7.55	110	3
A-076	11.70	0.05	0.00	3.20	12.43	63	4
A-077	15.10	0.00	0.09	0.10	15.14	133	4
A-078	6.79	0.05	0.57	0.00	6.88	104	3
A-079	11.85	1.10	0.00	0.00	11.96	138	4
A-080	14.29	0.23	0.02	0.20	14.36	105	4
A-081	12.40	1.01	0.12	0.00	12.50	175	4
A-082	13.30	0.00	0.07	0.00	13.31	92	4
A-083	11.45	0.00	0.77	0.60	11.72	157	3
A-084	7.73	0.00	1.25	1.50	8.28	105	3
A-085	6.66	1.20	2.33	0.00	7.21	98	3
A-086	12.21	0.00	12.89	0.40	14.91	105	4
A-087	12.80	0.26	0.18	2.10	13.32	157	4
A-088	15.15	0.00	0.01	0.00	15.15	105	4
A-089	18.10	0.25	0.20	1.00	18.35	231	4
A-090	18.65	3.95	0.75	0.30	19.27	273	4

TABLE 4 (continued).

Plot No.	Dead Branches	Slight Chlor	Strong Chlor	Small Leaves	Decline Index	Total Defects	Crown Class
A-091	20.05	0.65	0.33	2.60	20.70	294	4
A-092	11.60	0.00	0.46	0.00	11.67	140	4
A-093	14.90	0.00	1.70	0.65	15.23	129	4
A-094	14.40	1.45	0.83	0.90	14.81	122	4
A-095	15.70	5.55	10.60	0.00	18.44	133	4
A-096	15.65	2.90	0.73	6.15	17.11	280	4
A-097	16.55	6.59	1.51	2.45	17.73	265	4
A-098	18.15	2.86	1.07	1.75	19.01	339	4
A-099	14.45	2.85	0.77	0.04	14.90	174	4
A-100	13.85	4.55	0.31	0.00	14.43	161	4
A-101	13.25	5.65	1.27	0.00	14.15	166	4
A-102	10.15	2.25	0.10	0.70	10.51	160	4
A-103	15.55	3.56	0.81	0.36	16.26	204	4
A-104	11.70	7.74	1.40	0.00	12.70	157	3
A-105	11.60	3.50	0.72	0.35	12.18	181	4
A-106	15.40	6.35	2.81	0.00	16.47	146	4
A-107	11.76	0.01	1.67	0.90	12.10	156	3
A-108	13.05	0.40	0.54	1.55	13.54	131	4
A-109	18.59	5.87	0.50	0.00	18.98	179	4
A-110	13.20	0.16	0.09	0.00	13.23	182	4

TABLE 5: Summary of field observations for sugar maples only.

PLOT NUMBER	TREE SPECIES	NO. TREES	DBH	HEIGHT	AGE	DEAD BRANCHES	SLIGHT CHLOROSIS	STRONG CHLOROSIS	SMALL LEAVES	DECLINE INDEX	MEDIAN CROWN CLASS
A-001	Mh	78	15.2	14.9		12	11	1	0	13	4
A-002	Mh	63	20.5	19.7	102	10	5	3	0	11	3
A-003	Mh	72	20.7	20.0		12	5	0	0	12	4
A-004	Mh	79	22.4	17.2		10	5	2	0	11	4
A-005	Mh	54	29.2	20.5	101	10	9	7	0	12	4
A-006	Mh	93	33.5	25.4	107	10	2	3	0	11	4
A-007	Mh	83	35.3	26.6	103	8	5	3	0	9	3
A-008	Mh	28	28.7	20.7	76	10	3	2	0	10	4
A-009	Mh	73	22.0	19.1	89	11	2	15	0	15	4
A-010	Mh	68	20.9	18.1	82	8	5	18	0	13	3
A-011	Mh	56	24.7	16.3		14	3	5	0	15	4
A-012	Mh	73	20.4	19.2	85	5	0	6	0	7	3
A-013	Mh	84	21.9	16.5	74	18	10	3	0	20	4
A-014	Mh	84	22.1	20.1	81	10	3	2	0	11	3
A-015	Mh	91	22.6	14.5		13	3	4	0	14	4
A-016	Mh	62	19.9	17.4	107	11	5	1	4	13	4
A-017	Mh	76	17.3	12.9	80	21	0	18	0	25	4
A-018	Mh	76	25.3	17.4	82	10	0	2	0	11	4
A-019	Mh	96	36.9	27.9	102	11	1	3	0	12	3
A-020	Mh	87	26.8	21.4	90	10	11	11	0	13	3
A-021	Mh	85	26.6	22.0	85	10	4	2	0	11	4
A-022	Mh	88	20.1	19.5	95	7	2	0	0	8	3
A-023	Mh	77	20.8	18.9	101	8	2	1	0	9	3
A-024	Mh	62	22.7	18.3	90	8	2	12	0	11	3
A-025	Mh	54	24.2	21.1		7	0	0	0	8	3
A-026	Mh	62	19.2	18.4	85	15	4	1	0	16	4
A-027	Mh	67	21.7	18.4	115	8	5	1	1	9	3
A-028	Mh	84	19.2	17.7	82	14	1	1	0	14	4
A-029	Mh	66	19.6	18.4	90	15	1	3	0	15	4
A-030	Mh	89	25.2	21.6	109	17	3	0	0	17	4
A-031	Mh	83	16.9	15.5		11	2	1	0	11	4
A-032	Mh	66	23.1	16.5	91	9	2	0	0	9	4
A-033	Mh	54	21.3	17.5		10	5	1	1	12	4
A-034	Mh	56	25.2	18.5	118	11	0	4	0	12	3
A-035	Mh	66	16.7	14.5	69	10	3	3	0	11	3
A-036	Mh	80	28.2	19.5		11	0	0	0	11	3
A-037	Mh	63	26.2	22.1		26	28	10	0	30	4
A-038	Mh	73	20.3	18.0		17	22	5	0	20	4
A-039	Mh	81	20.0	15.1	72	11	3	5	0	13	3

TABLE 5: (continued).

PLOT NUMBER	TREE SPECIES	NO. TREES	DBH	HEIGHT	AGE	DEAD BRANCHES	SLIGHT CHLOROSIS	STRONG CHLOROSIS	SMALL LEAVES	DECLINE INDEX	MEDIAN CROWN CLASS
A-040	Mh	53	27.3	19.9	76	9	2	1	0	9	3
A-041	Mh	88	26.5	19.4	63	16	8	2	0	17	4
A-042	Mh	92	34.1	29.5	102	4	0	8	0	6	3
A-043	Mh	90	28.7	25.6	60	14	1	1	5	15	4
A-044	Mh	67	27.3	22.0	85	12	0	0	2	12	0
A-045	Mh	82	24.7	22.9	74	17	0	0	0	17	4
A-046	Mh	55	27.7	25.3	69	8	0	1	4	9	3
A-047	Mh	75	29.2	25.6	65	14	1	0	4	15	4
A-048	Mh	76	28.7	25.6	93	9	0	0	0	9	3
A-049	Mh	78	25.0	28.3	71	12	0	2	1	13	4
A-050	Mh	57	28.6	26.2	80	15	0	1	1	16	3
A-051	Mh	63	24.8	25.0	74	12	0	0	3	13	4
A-052	Mh	83	23.8	24.5	79	14	0	1	1	14	4
A-053	Mh	80	17.8	20.4	63	10	0	0	1	10	4
A-054	Mh	76	26.0	21.6	100	6	1	1	0	7	3
A-055	Mh	78	21.6	23.8	60	15	0	1	5	16	4
A-056	Mh	94	25.4	27.0	67	16	0	1	0	16	4
A-057	Mh	91	26.0	19.6	87	5	0	0	0	5	3
A-058	Mh	68	23.0	20.4	84	9	6	1	0	10	3
A-059	Mh	74	22.7	19.7	62	8	0	0	0	8	3
A-060	Mh	86	25.0	21.4	64	4	0	0	0	4	2
A-061	Mh	78	23.7	22.4		16	0	1	4	16	4
A-062	Mh	71	21.1	22.4	67	7	0	1	0	7	3
A-063	Mh	59	20.8	20.2	90	8	1	1	2	9	3
A-064	Mh	72	25.7	22.5		16	0	3	0	17	4
A-065	Mh	60	20.5	17.5	71	13	0	2	0	13	4
A-066	Mh	56	28.0	21.4		16	2	1	0	16	4
A-067	Mh	75	27.9	21.6	87	14	1	0	12	17	4
A-068	Mh	92	21.4	22.3	63	16	0	0	6	17	4
A-069	Mh	61	22.7	23.2	60	11	4	1	1	12	4
A-070	Mh	74	26.1	24.6	81	10	0	0	2	11	3
A-071	Mh	79	22.7	19.1	119	12	3	1	1	13	4
A-072	Mh	70	21.9	20.0		1	1	1	0	1	2
A-073	Mh	92	31.3	25.2	103	10	0	1	0	10	3
A-074	Mh	77	24.8	23.6	79	5	0	0	0	5	2
A-075	Mh	59	24.4	22.8	108	5	1	0	0	6	3
A-076	Mh	67	22.0	24.7	73	11	0	0	5	12	3
A-077	Mh	56	17.9	18.5	79	10	0	0	0	10	4
A-078	Mh	84	20.6	21.6	64	7	0	1	0	7	3
A-079	Mh	69	22.5	21.2	97	11	0	0	0	11	4

TABLE 5: (continued).

PLOT NUMBER	TREE SPECIES	NO. TREES	DBH	HEIGHT	AGE	DEAD BRANCHES	SLIGHT CHLOROSIS	STRONG CHLOROSIS	SMALL LEAVES	DECLINE INDEX	MEDIAN CROWN CLASS
A-080	Mh	44	25.4	19.1	97	14	1	0	0	14	4
A-081	Mh	50	24.7	21.6	104	8	0	0	0	8	3
A-082	Mh	67	27.3	21.4	114	14	0	0	0	14	4
A-083	Mh	70	20.1	19.6	86	7	0	0	0	8	3
A-084	Mh	75	26.0	21.8	100	4	0	0	0	4	3
A-085	Mh	89	21.7	22.3	63	5	0	2	0	5	3
A-086	Mh	62	23.6	20.8	84	10	0	11	0	12	4
A-087	Mh	100	35.4	28.0	77	13	0	0	2	13	4
A-088	Mh	46	19.3	20.6	73	9	0	0	0	9	4
A-089	Mh	80	17.5	16.7	74	15	0	0	1	15	4
A-090	Mh	69	28.6	20.7	98	16	6	1	0	17	4
A-091	Mh	92	22.2	18.7	70	18	1	0	3	19	4
A-092	Mh	94	25.7	20.2	102	10	0	0	0	10	3
A-093	Mh	79	20.3	17.8	65	12	0	0	0	12	4
A-094	Mh	70	21.4	19.1	78	16	2	1	0	16	4
A-095	Mh	95	25.8	20.1	122	15	6	11	0	18	4
A-096	Mh	98	30.0	20.9	93	16	3	1	6	17	4
A-097	Mh	97	25.0	20.7	88	16	7	2	3	18	4
A-098	Mh	85	19.5	20.6	62	17	3	1	2	18	4
A-099	Mh	86	24.4	20.6	75	16	3	1	0	16	4
A-100	Mh	63	23.4	20.3	81	14	7	0	0	15	4
A-101	Mh	87	24.7	23.1	78	12	4	1	0	13	4
A-102	Mh	81	19.7	21.4	75	9	2	0	1	10	4
A-103	Mh	71	22.9	18.3	87	11	2	1	1	11	3
A-104	Mh	67	24.6	20.2	81	14	11	2	0	16	4
A-105	Mh	100	21.9	18.7	70	12	4	1	0	12	4
A-106	Mh	72	25.2	19.0	136	13	8	3	0	15	4
A-107	Mh	95	18.7	17.9	70	10	0	2	0	11	3
A-108	Mh	91	20.7	16.7	78	13	0	1	2	13	4
A-109	Mh	89	27.1	18.8		17	1	0	0	17	4
A-110	Mh	74	18.1	15.5		14	0	0	0	14	4

Table 6

Mean Decline Index (all species) for each Forest Section* in Ontario.

Forest Region	Forest Section*	Mean DI	No. of Plots	% of Total
GL-St. L	1 Huron-Ontario	10.9	18	16.4
GL-St. L	2 Upper St. Lawrence	12.1	11	10.0
GL-St. L	4C Middle Ottawa	13.6	6	5.5
GL-St. L	4B Algonquin-Pontiac	14.0	16	14.5
Decid.	1 Niagara	14.4	20	18.2
GL-St. L	11 Quetico	15.3	3	2.7
GL-St. L	10 Algoma	15.5	11	10.0
GL-St. L	4E Sudbury-North Bay	15.7	13	11.8
GL-St. L	4D Georgian Bay	17.3	12	10.9
Least Significant Difference (at <0.01)		4.7		
Total		Mean (14.3)	110	100.0

* As defined by Rowe (1972), there are only two forest regions in Ontario: The Great Lakes St. Lawrence (GL-St. L) and the Deciduous (Decid.); whereas there are 9 forest sections within the forest regions.

TABLE 7: Summary of number of trees surveyed, mean decline index and mean number of defects for each tree species, in decreasing order of decline index.

Hardwood Species		Number of Trees	% of Total	Mean Decline Index	Mean No. Defects
Ew	American Elm	15	0.14	53	0.9
Ow	White Oak	5	0.05	42	0.6
Pol	Largetooth Aspen	19	0.17	36	0.7
Ob	Bur Oak	2	0.02	33	0.5
Cb	Black Cherry	175	1.59	28	0.8
Ww	Weeping Willow	2	0.02	28	0.0
Bn	Butternut	5	0.05	27	1.0
Potr	Trembling Aspen	64	0.58	25	1.3
Bw	White Birch	111	1.01	24	1.4
I	Ironwood	292	2.65	23	1.1
Poba	Balsam Poplar	34	0.31	23	1.6
Mr	Red Maple	339	3.08	22	1.7
Or	Red Oak	159	1.45	20	0.8
By	Yellow Birch	181	1.65	20	1.7
Bd	Basswood	332	3.02	18	1.2
Aw	White Ash	407	3.70	17	0.7
Hb	Bitternut Hickory	93	0.85	14	0.5
Be	Beech	334	3.04	13	1.1
Mh	Sugar Maple	8227	74.79	12	1.4
Cr	Pin Cherry	6	0.05	12	1.8
Ab	Black Ash	39	0.35	12	0.9
Hi	Hickory	3	0.03	10	0.7
Ag	Green Ash	2	0.02	8	1.0
ALL		10846	98.6	14	1.3

Conifer Species

Species		Number of Trees	% of Total	Average Decline Index
Ce	White Cedar	15	0.14	n/a
He	Hemlock	85	0.77	n/a
Bf	Balsam Fir	25	0.23	n/a
Pw	White Pine	20	0.18	n/a
Sw	White Spruce	8	0.07	n/a
L	Larch	1	0.01	n/a
ALL		154	1.4	

TABLE 8: Sum of tree quality defects noted for sugar maples in each study plot.

Plot Number	Frost Cracks	Open Wounds	Cankers	Conks	Heart Rot	Root Rot (Armillaria)	Total Insects	Mites	Total Defects	No. of Trees
A-001	13	23	2	5	1	0	77	19	140	78
A-002	26	22	3	3	0	0	59	36	149	63
A-003	15	13	1	10	0	0	58	13	110	72
A-004	46	38	2	7	10	0	63	31	197	79
A-005	16	20	1	1	2	0	53	19	112	54
A-006	27	36	4	3	3	3	78	0	154	93
A-007	34	42	1	8	7	1	66	0	159	83
A-008	5	10	0	3	6	1	21	1	47	28
A-009	1	13	0	2	0	0	38	0	54	73
A-010	3	23	0	5	1	0	62	0	94	68
A-011	22	26	0	4	9	0	56	0	117	56
A-012	17	10	0	1	0	2	70	0	100	73
A-013	25	37	7	9	3	1	62	16	160	84
A-014	15	19	1	1	0	2	79	1	118	84
A-015	17	24	1	7	2	1	53	0	105	91
A-016	7	15	0	3	3	0	62	20	110	62
A-017	28	27	8	7	3	0	69	0	142	76
A-018	49	29	6	7	9	0	51	0	151	76
A-019	22	3	0	3	0	0	55	3	86	96
A-020	10	15	1	2	3	0	44	0	75	87
A-021	16	21	1	6	4	7	76	1	132	85
A-022	6	9	1	4	1	0	55	0	76	88
A-023	20	16	2	3	1	0	68	0	110	77
A-024	15	10	4	2	2	2	31	0	66	62
A-025	10	7	0	2	1	0	52	0	72	54
A-026	34	19	4	4	3	0	28	4	96	62
A-027	22	23	2	1	6	0	66	30	150	67
A-028	14	12	1	2	1	0	69	5	104	84
A-029	6	15	1	2	1	0	62	5	92	66
A-030	54	56	5	23	10	0	88	0	236	89
A-031	40	15	1	10	2	0	66	7	141	83
A-032	18	21	2	4	6	0	31	0	82	66
A-033	12	22	2	1	4	0	46	13	100	54
A-034	12	13	0	2	2	0	51	0	80	56
A-035	4	16	1	7	4	0	18	0	50	66
A-036	35	18	1	2	2	0	79	1	138	80
A-037	12	12	0	1	3	0	61	0	89	63
A-038	10	17	2	4	1	1	69	1	105	73
A-039	16	15	1	5	1	1	18	0	57	81
A-040	23	6	1	5	2	1	39	0	77	53
A-041	2	16	2	0	1	0	49	0	70	88
A-042	6	17	1	2	3	10	74	0	113	92
A-043	0	31	5	31	10	0	34	4	115	90
A-044	1	17	0	19	13	0	1	0	51	67
A-045	3	17	1	7	10	0	0	0	38	82
A-046	0	5	2	1	1	0	13	3	25	55

TABLE 8 (continued).

Plot Number	Frost Cracks	Open Wounds	Cankers	Conks	Heart Rot	Root Rot (Armillaria)	Total Insects	Mites	Total Defects	No. of Trees
A-047	0	14	1	0	5	0	26	0	46	75
A-048	0	11	7	4	5	2	24	0	53	76
A-049	0	7	3	1	4	0	16	2	33	78
A-050	1	18	5	2	8	0	12	1	47	57
A-051	50	16	2	11	3	1	8	2	93	63
A-052	3	14	3	0	2	0	40	11	73	83
A-053	0	9	3	3	0	0	13	4	32	80
A-054	6	17	0	2	1	0	42	0	68	76
A-055	0	9	0	16	4	0	27	0	56	78
A-056	1	30	1	29	21	2	34	8	126	94
A-057	6	11	1	2	3	1	5	0	29	91
A-058	5	20	1	5	4	0	61	36	132	68
A-059	0	6	1	0	3	0	74	0	84	74
A-060	1	17	1	4	23	0	10	1	57	86
A-061	5	6	17	4	1	0	39	1	73	78
A-062	16	16	1	2	2	0	63	0	100	71
A-063	4	4	17	2	0	1	12	0	40	59
A-064	8	10	18	1	7	1	34	0	79	72
A-065	13	15	0	3	4	0	51	0	86	60
A-066	7	19	15	3	4	0	30	3	81	56
A-067	20	27	2	14	13	0	63	34	173	75
A-068	2	15	3	10	7	1	20	0	58	92
A-069	1	24	4	1	8	0	17	9	64	61
A-070	0	7	1	1	2	0	14	1	26	74
A-071	37	38	3	2	4	1	64	11	160	79
A-072	1	7	0	1	6	0	0	0	15	70
A-073	7	27	2	1	20	0	75	0	132	92
A-074	2	13	0	0	3	0	0	0	18	77
A-075	1	23	1	0	14	0	28	0	67	59
A-076	0	14	4	2	5	1	15	0	41	67
A-077	3	6	2	1	0	0	49	39	100	56
A-078	8	28	1	6	12	0	41	0	96	84
A-079	3	19	3	2	1	0	46	7	81	69
A-080	0	12	0	1	2	0	21	8	44	44
A-081	6	10	0	0	4	0	12	0	32	50
A-082	3	13	1	0	2	0	24	15	58	67
A-083	13	26	0	8	8	0	57	0	112	70
A-084	8	11	3	2	8	0	46	0	78	75
A-085	5	17	1	1	0	0	64	0	88	89
A-086	20	15	0	4	0	2	23	0	64	62
A-087	6	30	3	12	10	1	63	32	157	100
A-088	0	5	0	1	0	0	40	24	70	46
A-089	35	40	6	8	8	0	67	40	204	80
A-090	33	37	11	9	5	0	68	45	208	69
A-091	47	59	16	10	32	0	80	39	283	92
A-092	34	30	4	7	3	0	52	0	130	94
A-093	6	19	0	1	3	0	77	0	106	79
A-094	12	13	0	1	2	0	67	0	95	70
A-095	10	17	1	0	4	0	94	0	126	95

TABLE 8 (continued).

Plot Number	Frost Cracks	Open Wounds	Cankers	Conks	Heart Rot	Root Rot (Armillaria)	Total Insects	Mites	Total Defects	No. of Trees
A-096	45	54	21	13	17	0	98	29	277	98
A-097	25	36	14	30	3	0	95	51	254	97
A-098	48	39	12	46	16	1	72	49	283	85
A-099	18	41	6	34	6	0	40	11	156	86
A-100	12	23	3	17	11	0	44	25	135	63
A-101	21	35	2	13	12	0	53	9	145	87
A-102	3	22	0	1	2	0	78	29	135	81
A-103	6	33	4	9	15	1	55	38	161	71
A-104	19	19	0	4	5	0	65	13	125	67
A-105	6	37	3	6	6	2	100	21	181	100
A-106	12	20	3	4	5	1	60	3	108	72
A-107	38	26	2	6	2	0	76	1	151	95
A-108	25	37	2	13	7	0	37	3	124	91
A-109	18	30	1	9	10	0	55	42	165	89
A-110	10	21	3	4	5	0	72	19	134	74

TABLE 9: Pearson correlation matrix for decline index and various tree quality defects.

	Decline Index	Frost Cracks	Conks	Open Wounds	Insects
Decline Index	-----				
Frost Cracks	0.200	-----			
Conks	0.267	0.315	-----		
Open Wounds	0.252	0.588	0.484	-----	
Insects	0.195	0.477	-0.002	0.371	-----
Mites	0.278	0.288	0.383	0.545	0.328
Cankers	0.417	0.240	0.267	0.280	0.059
Root Rot	-0.126	0.006	0.008	0.011	0.058
Heart Rot	0.056	0.117	0.368	0.588	-0.082
Total Defects	0.341	0.782	0.408	0.745	0.729

	Mites	Cankers	Root Rot	Heart Rot	Total Defects
Mites	-----				
Cankers	0.300	-----			
Root Rot	-0.110	-0.009	-----		
Heart Rot	0.319	0.220	-0.050	-----	
Total Defects	0.575	0.271	0.035	0.285	-----

NUMBER OF OBSERVATIONS: 110

Significance Level	Critical r-value (100+ d.f.)
5% (.05)	0.195
1% (.01)	0.254

Factors Correlated with Decline Index, Ranked in Order of Significance
(Factors Significant at 1% level)

1. Cankers
2. Total defects
3. Mites
4. Conks
5. Open wounds
6. Frost cracks

TABLE 10: Results of Analysis of Variance for Decline Index, between Forest Sectors and between MNR Administrative Districts.

ANALYSIS OF VARIANCE - FOREST SECTORS

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F	PROBABILITY
BETWEEN GROUPS	316.315	9	35.146	3.473	.001 (99.9%)
WITHIN GROUPS	1011.917	100	10.119		

ANALYSIS OF VARIANCE - MNR DISTRICTS

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F	PROBABILITY
BETWEEN GROUPS	717.358	26	27.591	3.749	.000 (99.9+%)
WITHIN GROUPS	610.874	83	7.360		

TABLE 11: Summary of Decline Index Averages for each MNR Administrative District. Districts are subdivided into 'Southern Ontario' and 'Northern Ontario' groups.

ZONE	DISTRICT	NO.PLOTS	MEAN DECLINE INDEX
S	Niagara	5	16.3
S	Cambridge	3	16.2
S	Aylmer	4	15.8
S	Carleton Place	2	15.3
S	Chatham	3	15.3
S	Simcoe	2	13.7
S	Tweed	3	12.9
S	Huronia	8	12.7
S	Napanee	2	12.5
S	Owen Sound	7	11.8
S	Cornwall	4	11.2
S	Brockville	3	11.0
S	Wingham	4	10.3
S	Maple	2	7.0
S	Lindsay	5	6.8
N	Sault Ste. Marie	6	18.1
N	Minden	5	17.8
N	Algonquin	4	17.2
N	Parry Sound	7	17.0
N	Sudbury	5	16.8
N	Espanola	7	15.4
N	Thunder Bay	3	15.3
N	North Bay	5	14.6
N	Pembroke	2	14.2
N	Bancroft	2	14.2
N	Bracebridge	2	12.8
N	Blind River	5	12.5

TABLE 12: Results of analyses of variance, decline index versus soil features influencing soil buffering capacity.

RESULTS OF ANALYSIS OF VARIANCE - DECLINE INDEX VS. SOIL DEPTH

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
BRCLASS	6.968	2	3.484	0.283	0.754 (24.6%)
ERROR	1305.261	106	12.314		

RESULTS OF ANALYSIS OF VARIANCE - DECLINE INDEX VS. DEPTH TO CARBONATES

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
CACLASS	35.642	2	17.821	1.480	0.232 (76.8%)
ERROR	1276.586	106	12.043		

RESULTS OF ANALYSIS OF VARIANCE - DECLINE INDEX VS. SOIL TEXTURE CLASS

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
TEXTURE	4.403	3	1.468	0.118	0.949 (5.1%)
ERROR	1307.826	105	12.455		

RESULTS OF ANALYSIS OF VARIANCE - DECLINE INDEX VS. SOIL MOISTURE REGIME

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
SOILMR	103.188	6	17.198	1.451	0.203 (79.7%)
ERROR	1209.040	102	11.853		

All results are non-significant.

TABLE 13: K-Means cluster analysis of hardwood decline plots using arcsin transformed values for % dead branches (TDEAD), % slight (TSLI) and strong chlorosis (TSTR) and % small leaves (TSMALL), generating 6 clusters.

SUMMARY STATISTICS FOR 6 CLUSTERS

VARIABLE	BETWEEN SS	DF	WITHIN SS	DF	F-RATIO	PROB
TDEAD	286.903	5	966.629	104	6.174	0.000
TSLI	2844.050	5	979.081	104	60.420	0.000
TSTR	2415.251	5	806.080	104	62.323	0.000
TSMALL	844.240	5	694.408	104	25.288	0.000

CLUSTER NUMBER: 1

MEMBERS

CASE	DISTANCE
A-049	3.16
A-056	2.28
A-045	3.59
A-019	3.44
A-052	2.22
A-059	1.86
A-073	1.16
A-074	4.20
A-060	3.33
A-072	4.53
A-057	2.61
A-075	4.14
A-053	2.93
A-102	3.42
A-085	3.69
A-084	3.48
A-088	3.11
A-048	2.39
A-078	2.43
A-077	2.65
A-034	2.64
A-032	1.61
A-040	1.74
A-110	1.93
A-082	2.47
A-083	1.95
A-025	1.59
A-023	2.60
A-022	3.30
A-062	2.09
A-054	1.65
A-080	2.28
A-081	2.18
A-079	2.83
A-018	1.89
A-092	1.79
A-093	3.08
A-107	2.64
A-029	4.49

STATISTICS

VARIABLE	MINIMUM	MEAN	MAXIMUM	ST.DEV.
TDEAD	12.00	19.25	27.10	3.36
TSLI	0.00	2.90	8.70	2.90
TSTR	0.00	4.23	10.70	2.80
TSMALL	0.00	1.97	7.00	2.10

TABLE 13 (continued)

CLUSTER NUMBER: 2

MEMBERS		STATISTICS				
CASE	DISTANCE	VARIABLE	MINIMUM	MEAN	MAXIMUM	ST.DEV.
A-069	1.35	TDEAD	16.40	22.14	27.20	2.57
A-058	2.06	TSLI	4.80	11.78	17.70	3.05
A-041	3.49	TSTR	1.70	7.69	13.00	2.76
A-103	1.50	TSMALL	0.00	2.42	9.40	2.67
A-105	1.92					
A-016	4.16					
A-027	2.32					
A-033	1.86					
A-035	3.53					
A-015	2.08					
A-013	3.49					
A-039	2.92					
A-109	2.96					
A-007	3.27					
A-014	2.09					
A-008	2.80					
A-006	2.84					
A-099	1.82					
A-098	3.31					
A-097	3.77					
A-005	3.83					
A-002	2.67					
A-021	1.82					
A-004	1.64					
A-003	3.23					
A-100	2.57					
A-066	3.32					
A-063	2.92					
A-064	4.21					
A-071	2.12					
A-090	2.22					
A-030	3.45					
A-106	2.17					
A-101	1.74					
A-104	2.77					
A-026	1.23					

TABLE 13 (continued)

CLUSTER NUMBER: 3

MEMBERS		STATISTICS				
CASE	DISTANCE	VARIABLE	MINIMUM	MEAN	MAXIMUM	ST.DEV.
A-042	4.68	TDEAD	12.30	20.16	27.10	4.12
A-086	3.38	TSLI	0.00	6.46	13.60	3.96
A-012	3.69	TSTR	15.40	20.18	28.60	3.65
A-011	2.39	TSMALL	0.00	1.80	6.10	2.16
A-010	2.54					
A-024	2.28					
A-009	1.36					
A-017	5.59					
A-095	4.05					

CLUSTER NUMBER: 4

MEMBERS		STATISTICS				
CASE	DISTANCE	VARIABLE	MINIMUM	MEAN	MAXIMUM	ST.DEV.
A-020	3.59	TDEAD	21.20	25.33	30.20	3.71
A-037	3.10	TSLI	18.60	23.03	25.50	3.14
A-038	2.47	TSTR	12.40	16.63	20.20	3.22
		TSMALL	0.00	1.43	4.30	2.03

TABLE 13 (continued)

CLUSTER NUMBER: 5

MEMBERS		STATISTICS				
CASE	DISTANCE	VARIABLE	MINIMUM	MEAN	MAXIMUM	ST.DEV.
A-050	2.77	TDEAD	19.00	22.65	26.60	2.06
A-070	1.76	TSLI	0.00	3.05	9.80	2.56
A-047	1.46	TSTR	0.00	3.60	6.60	1.84
A-044	2.40	TSMALL	5.40	9.02	17.50	3.10
A-051	1.84					
A-068	2.35					
A-055	2.13					
A-043	1.77					
A-087	1.08					
A-046	1.90					
A-076	2.48					
A-036	2.58					
A-108	1.23					
A-096	4.38					
A-061	2.07					
A-067	4.30					
A-065	2.45					
A-091	2.13					
A-089	2.15					
A-031	2.69					
A-094	2.77					
A-028	2.10					

CLUSTER NUMBER: 6

MEMBERS		STATISTICS				
CASE	DISTANCE	VARIABLE	MINIMUM	MEAN	MAXIMUM	ST.DEV.
A-001	0.00	TDEAD	21.30	21.30	21.30	0.00
		TSLI	22.90	22.90	22.90	0.00
		TSTR	5.00	5.00	5.00	0.00
		TSMALL	5.00	5.00	5.00	0.00

TABLE 14: Main analysis of variance between K-means cluster groups based on decline index. Group 6 was deleted from this analysis since it had only one member (and hence no variance).

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
CLUSTER	403.353	4	100.838	11.378	0.000
ERROR	921.725	104	8.863		

TABLE 15: Differences between cluster groups determined by ANOVAR; matrix of contrast F-ratios and significance levels.

F-Ratios

GROUP #	1	2	3	4	5
1	---				
2	24.679	---			
3	7.669	0.111	---		
4	21.042	7.091	6.690	---	
5	21.801	0.128	0.312	5.967	---

Probability Levels

GROUP #	1	2	3	4	5
1	---				
2	0.001	---			
3	0.01	ns **	---		
4	0.001	0.01	0.05	---	
5	0.001	ns **	ns **	0.05	---

Note: .05 = significantly different at 95% level
.01 = significantly different at 99% level
.001 = significantly different at 99.9% level
ns ** = not significant

Summary: Group 2 is not different from groups 3 and 5.
Group 3 is not different from group 5.
All other combinations of the cluster groups are significantly different.

TABLE 16: Descriptive statistics for the 6 K-means plot clusters, for decline index (DECNDX), diameter at breast height (DBH) and stand age.

THE FOLLOWING RESULTS ARE FOR:
CLUSTER = 1.000

TOTAL OBSERVATIONS: 39

	DECNDX	DBH	AGE
N OF CASES	39	39	36
MINIMUM	4.360	18.900	63.000
MAXIMUM	20.990	36.700	113.800
MEAN	11.378	23.972	84.586
STANDARD DEV	3.633	3.522	14.870
STD. ERROR	0.582	0.564	2.478

THE FOLLOWING RESULTS ARE FOR:
CLUSTER = 2.000

TOTAL OBSERVATIONS: 36

	DECNDX	DBH	AGE
N OF CASES	36	36	29
MINIMUM	9.150	18.900	59.800
MAXIMUM	21.860	57.740	132.600
MEAN	15.271	25.464	88.528
STANDARD DEV	3.036	6.464	19.082
STD. ERROR	0.506	1.077	3.543

THE FOLLOWING RESULTS ARE FOR:
CLUSTER = 3.000

TOTAL OBSERVATIONS: 9

	DECNDX	DBH	AGE
N OF CASES	9	9	8
MINIMUM	6.600	17.700	76.000
MAXIMUM	25.320	35.090	121.600
MEAN	15.054	24.109	91.325
STANDARD DEV	5.425	4.815	15.317
STD. ERROR	1.808	1.605	5.415

TABLE 16: (continued)

THE FOLLOWING RESULTS ARE FOR:
CLUSTER = 4.000

TOTAL OBSERVATIONS: 3

	DECNDX	DBH	AGE
N OF CASES	3	3	1
MINIMUM	16.480	20.600	85.000
MAXIMUM	28.740	27.300	85.000
MEAN	21.777	24.900	85.000
STANDARD DEV	6.298	3.732	0.000
STD. ERROR	3.636	2.155	0.000

THE FOLLOWING RESULTS ARE FOR:
CLUSTER = 5.000

TOTAL OBSERVATIONS: 22

	DECNDX	DBH	AGE
N OF CASES	22	22	19
MINIMUM	10.960	17.800	60.000
MAXIMUM	20.700	35.360	93.200
MEAN	15.592	25.765	73.887
STANDARD DEV	2.665	4.767	9.648
STD. ERROR	0.568	1.016	2.213

THE FOLLOWING RESULTS ARE FOR:
CLUSTER = 6.000

TOTAL OBSERVATIONS: 1

	DECNDX	DBH	AGE
MEAN	15.050	16.800	

TABLE 17: Average values for decline attributes and decline index for each K-means cluster group.

Decline Attribute	Cluster Group Number 1	2	3	4	5
Dead branches	10.9	14.2	11.9	18.3	14.8
Slight chlorosis	0.3	4.2	1.3	15.3	0.3
Strong chlorosis	0.5	1.8	11.9	8.2	0.4
Dwarfed leaves	0.1	0.2	0.1	0.1	2.5
Decline index	11.4	15.3	15.1	21.8	15.6

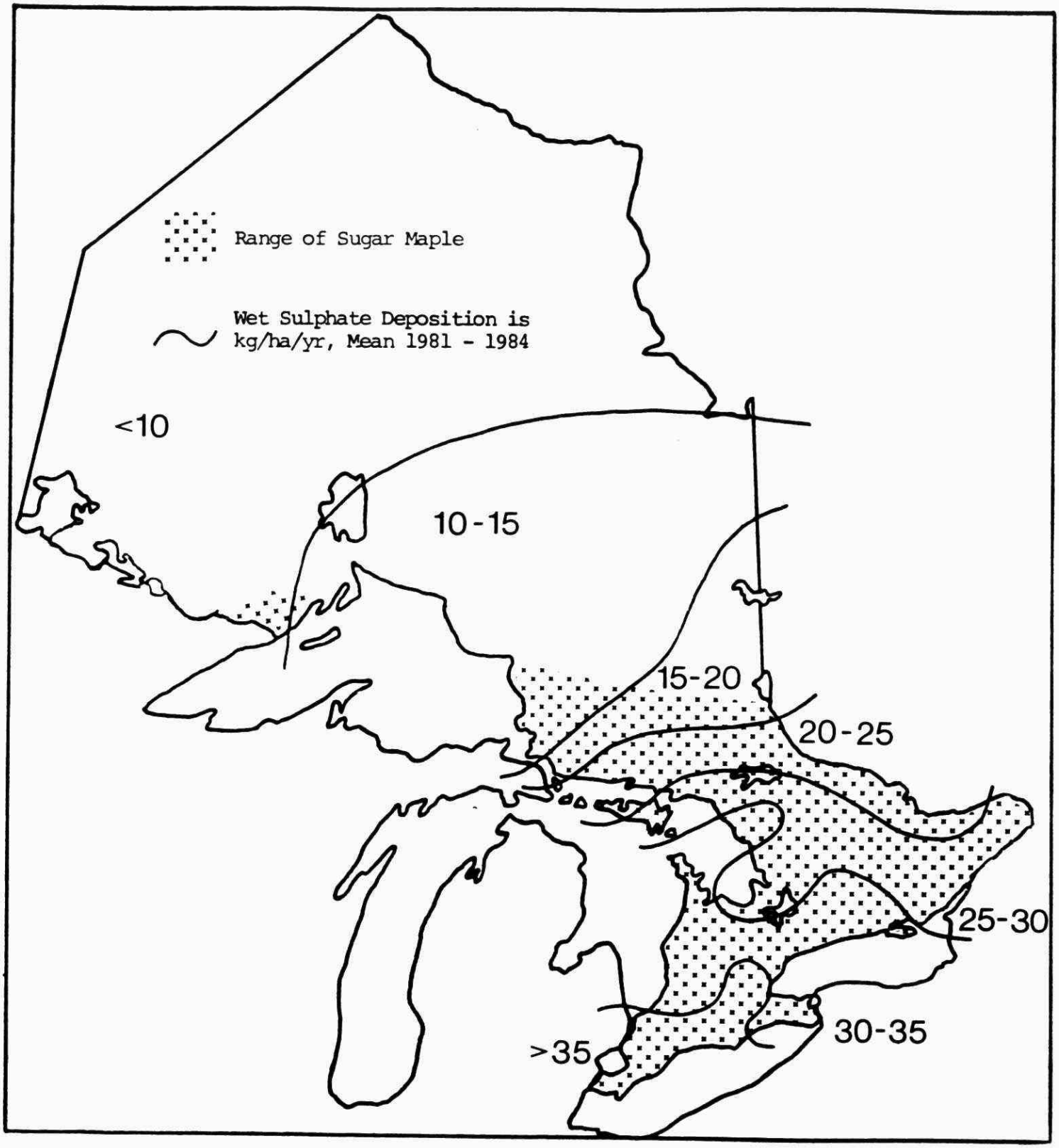


Figure 1: The range of sugar maple in Ontario and the average wet sulphate deposition over the four year period 1981 to 1984.

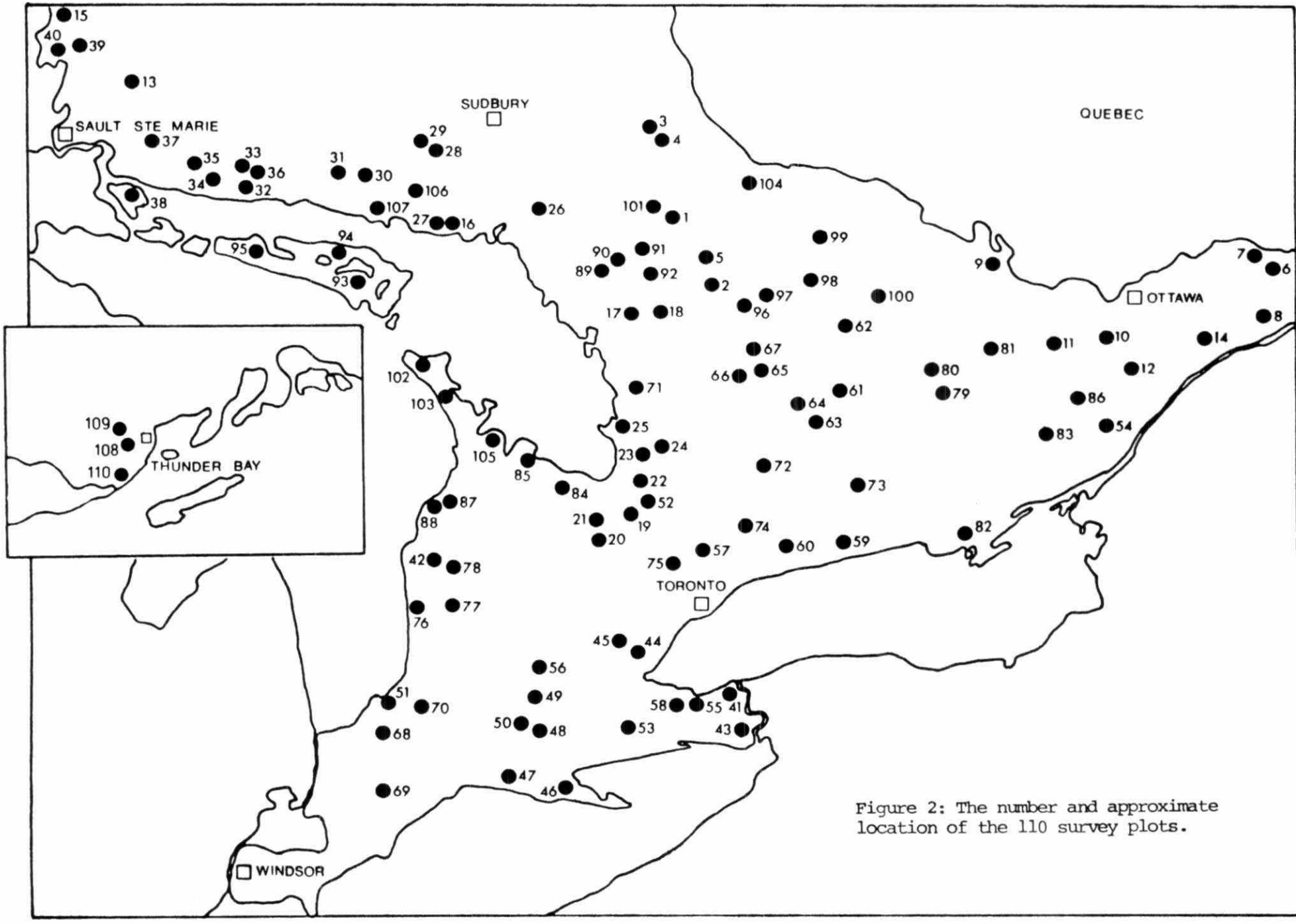


Figure 2: The number and approximate location of the 110 survey plots.

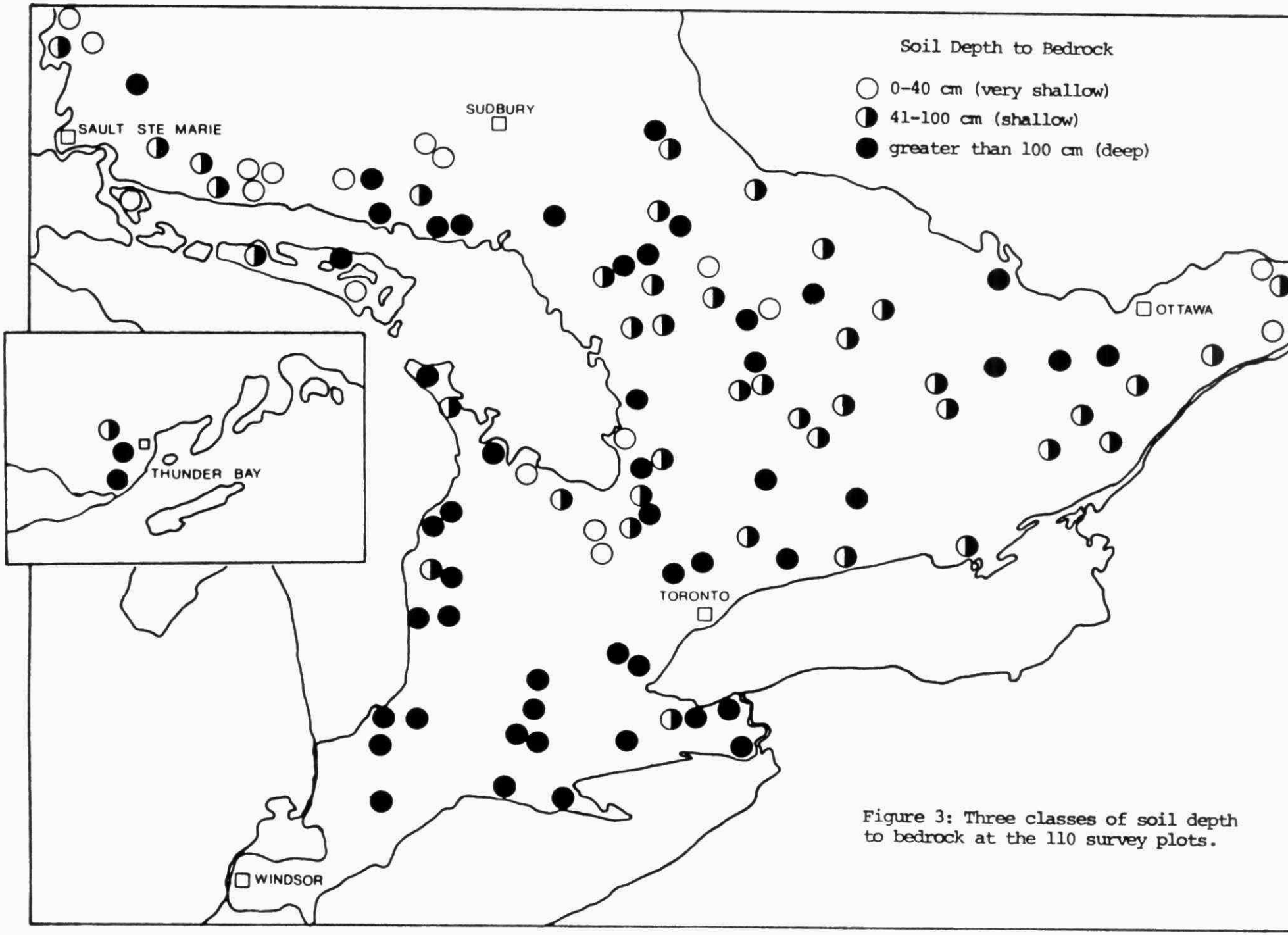


Figure 3: Three classes of soil depth to bedrock at the 110 survey plots.

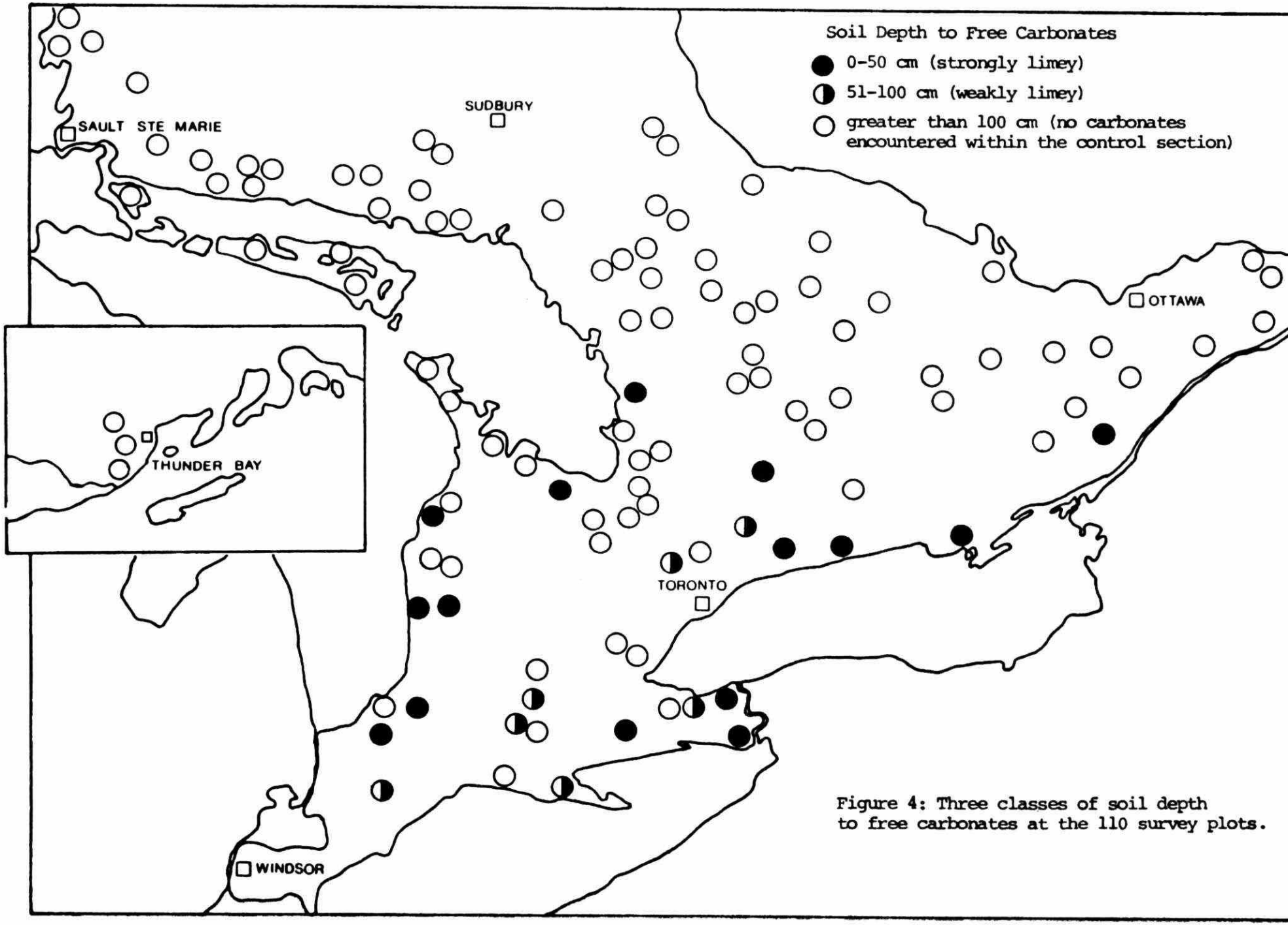


Figure 4: Three classes of soil depth to free carbonates at the 110 survey plots.

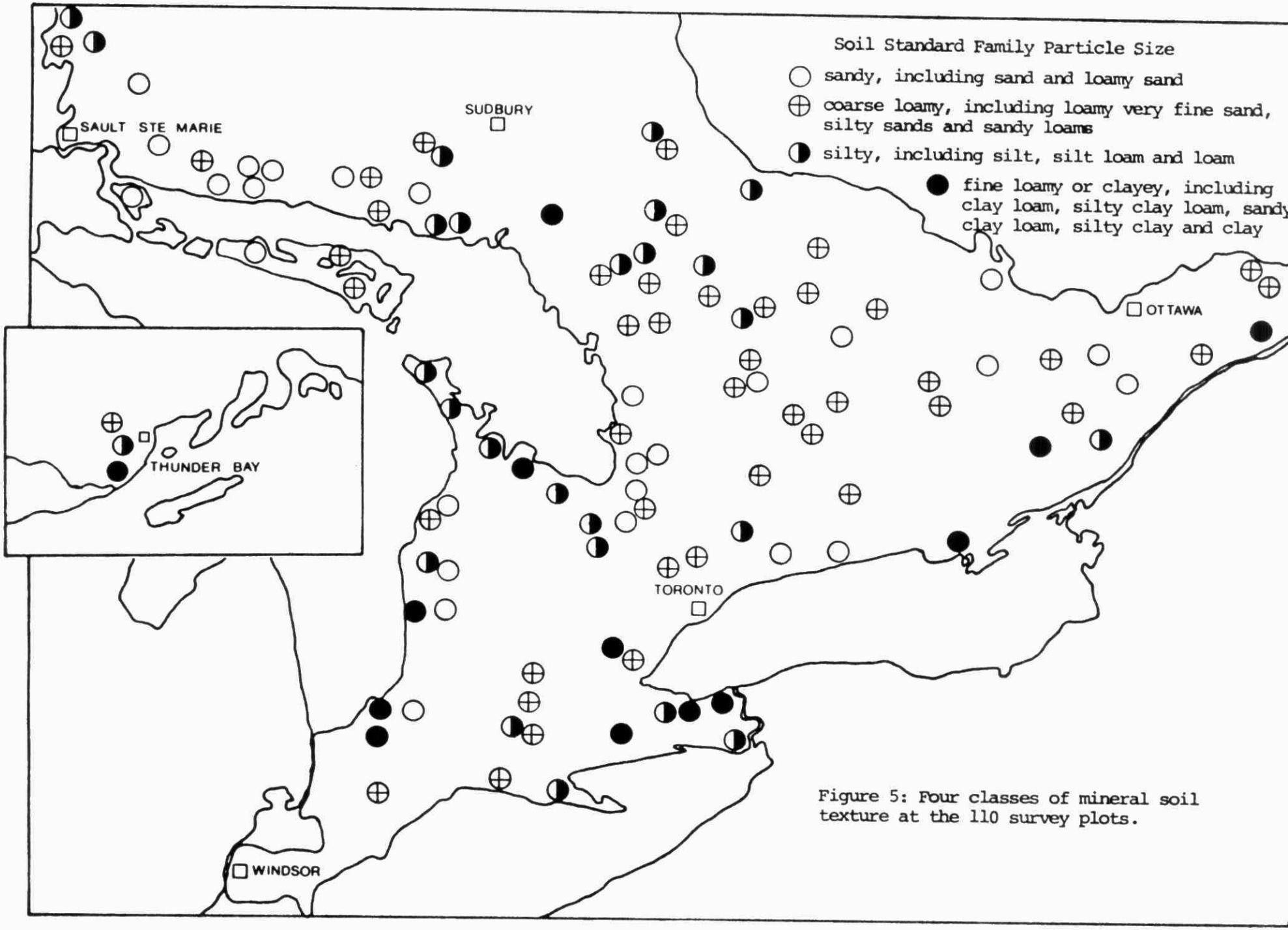

Soil Standard Family Particle Size
sandy, including sand and loamy sand
coarse loamy, including loamy very fine sand, silty sands and sandy loams
silty, including silt, silt loam and loam
fine loamy or clayey, including clay loam, silty clay loam, sandy clay loam, silty clay and clay
SAULT STE MARIE
SUDBURY
OTTAWA
THUNDER BAY
TORONTO
WINDSOR

Figure 5: Four classes of mineral soil texture at the 110 survey plots.

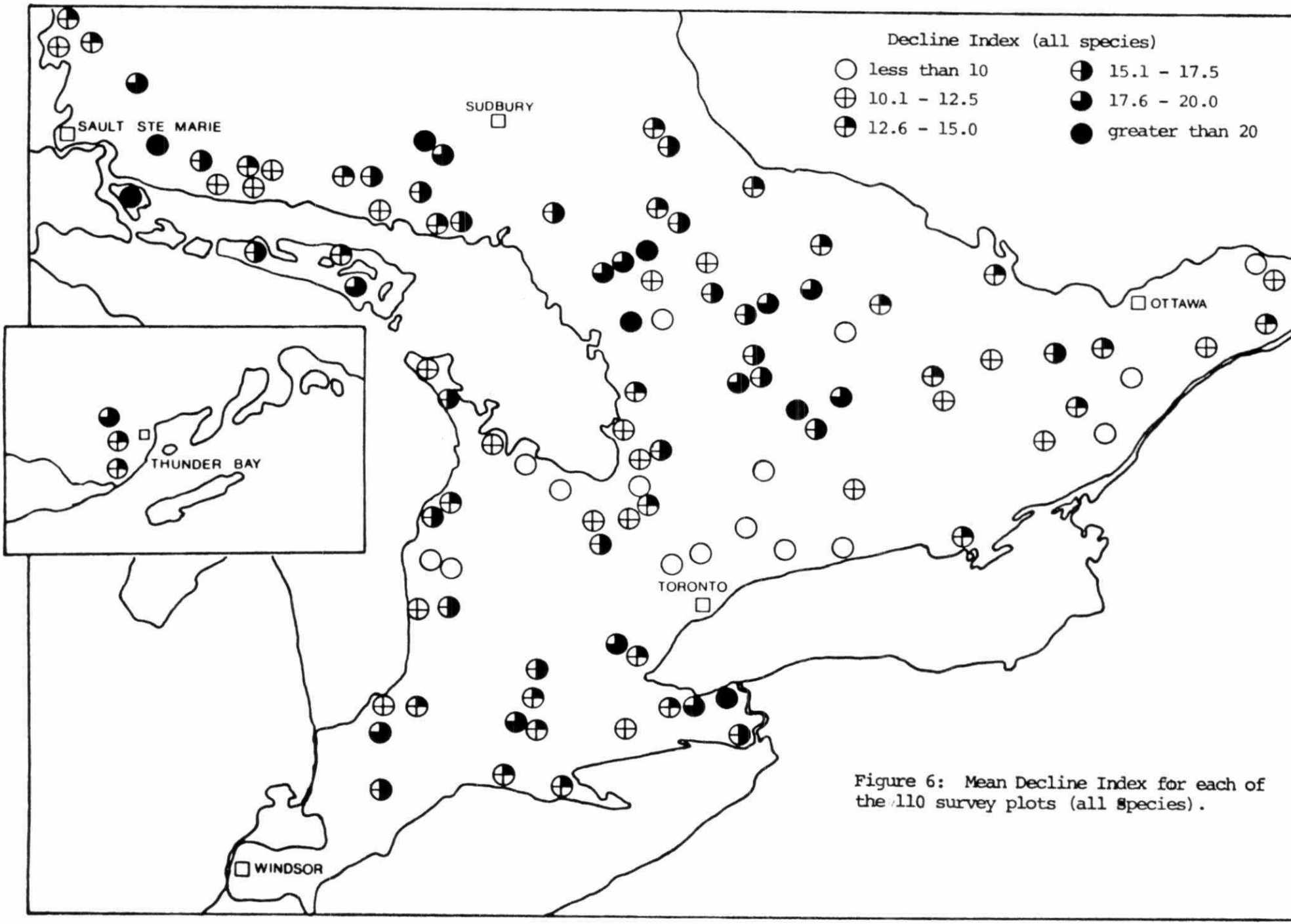


Figure 6: Mean Decline Index for each of the 110 survey plots (all species).

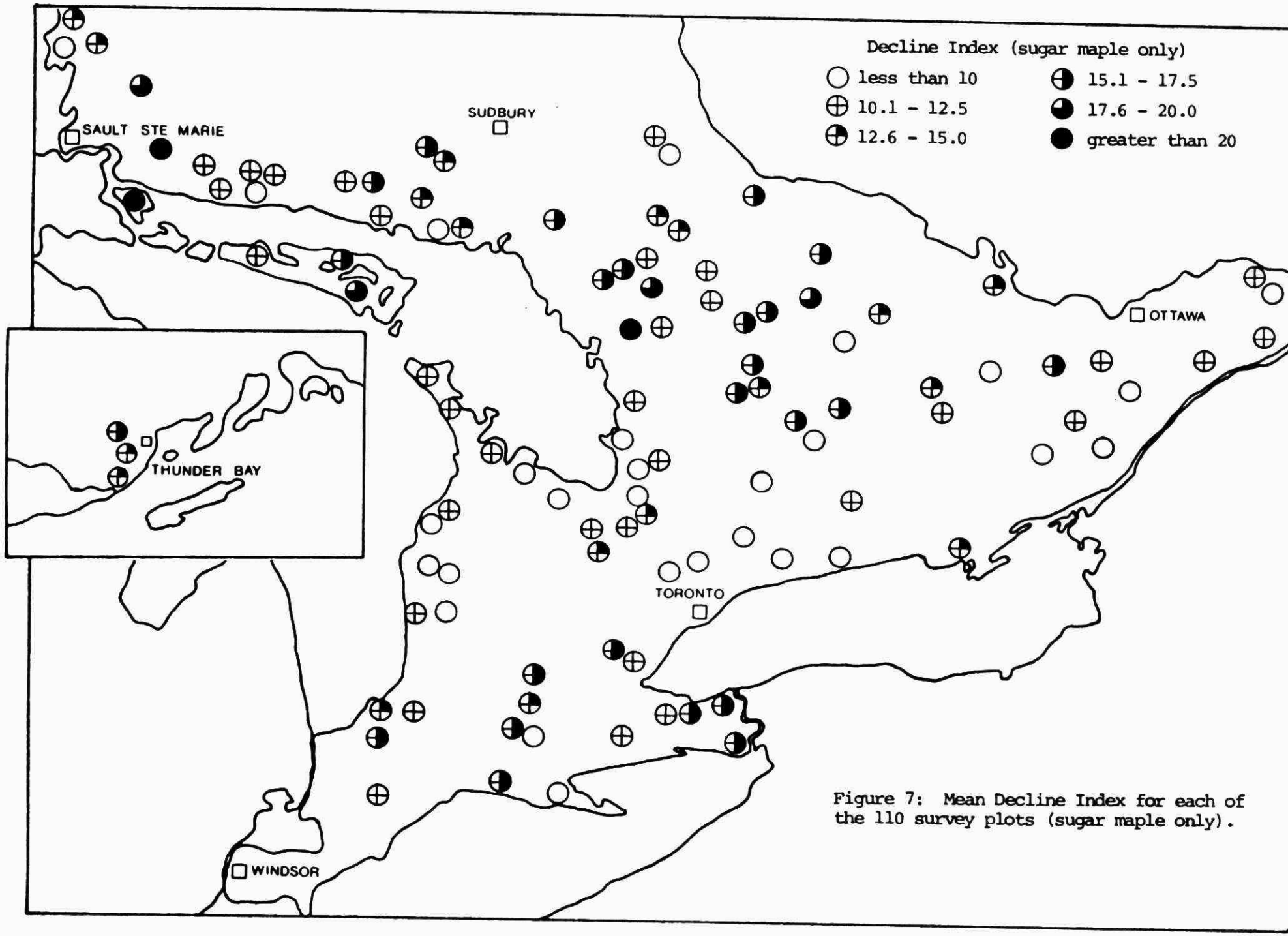
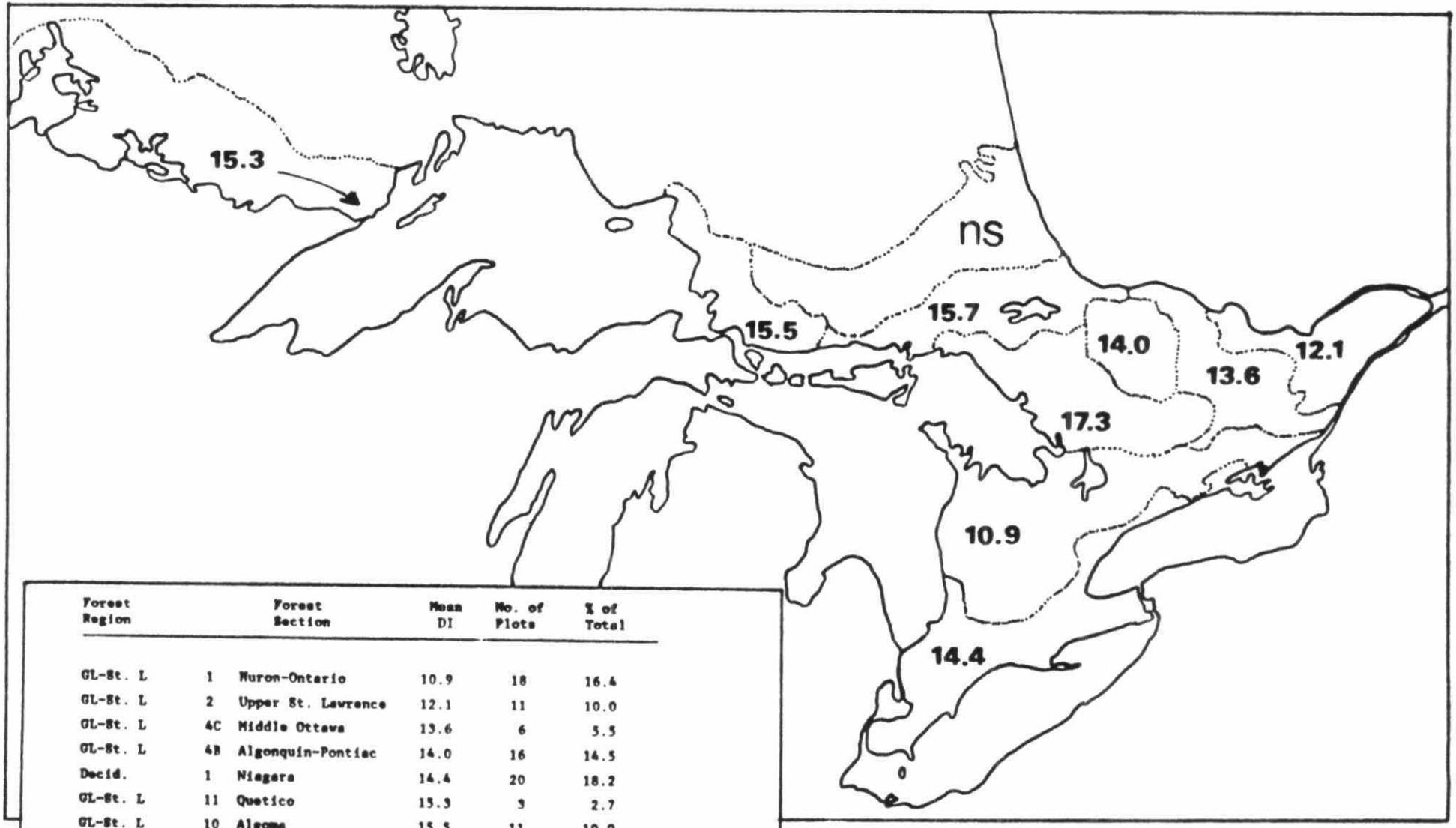


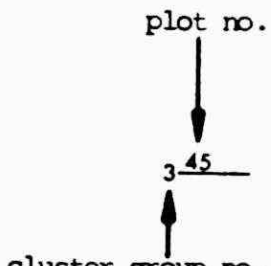
Figure 7: Mean Decline Index for each of the 110 survey plots (sugar maple only).



Forest Region		Forest Section	Mean DI	No. of Plots	% of Total
GL-St. L	1	Huron-Ontario	10.9	18	16.4
GL-St. L	2	Upper St. Lawrence	12.1	11	10.0
GL-St. L	4C	Middle Ottawa	13.6	6	5.5
GL-St. L	4B	Algonquin-Pontiac	14.0	16	14.5
Decid.	1	Niagara	14.4	20	18.2
GL-St. L	11	Quetico	15.3	3	2.7
GL-St. L	10	Algoma	15.5	11	10.0
GL-St. L	4E	Sudbury-North Bay	15.7	13	11.8
GL-St. L	4D	Georgian Bay	17.3	12	10.9
Least Significant Difference (at <0.01)			4.7		

forest classification after Rowe, 1972
ns region not surveyed

Figure 8: The mean Decline Index by forest section.



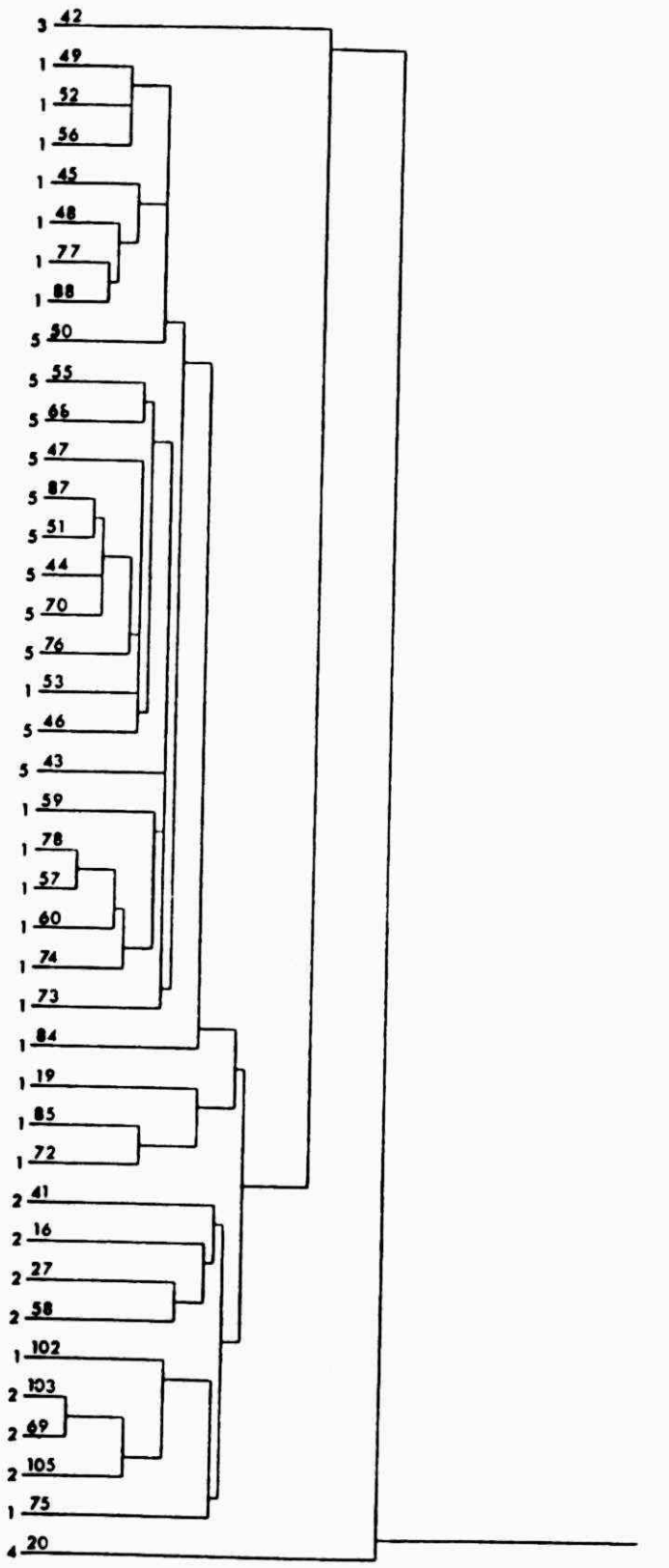
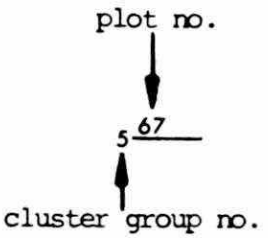
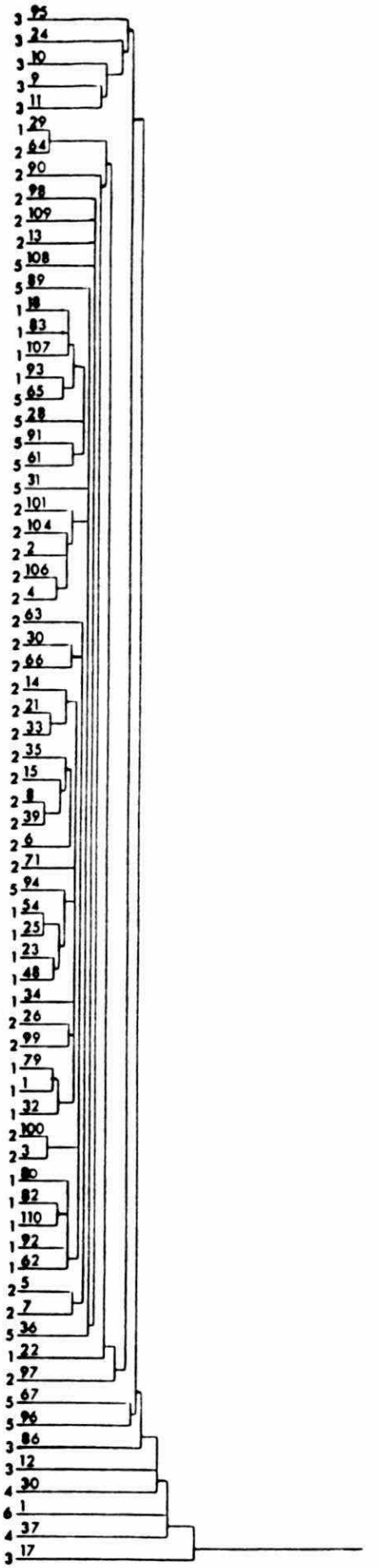


Figure 9: Dendrogram (tree diagram) developed from the K-means cluster analysis of the survey plot tree assessment data for the Deciduous forest region.

Figure 10: Dendrogram (tree diagram) developed from the K-means cluster analysis of the survey plot tree assessment data for the Great Lakes - St. Lawrence forest Region.





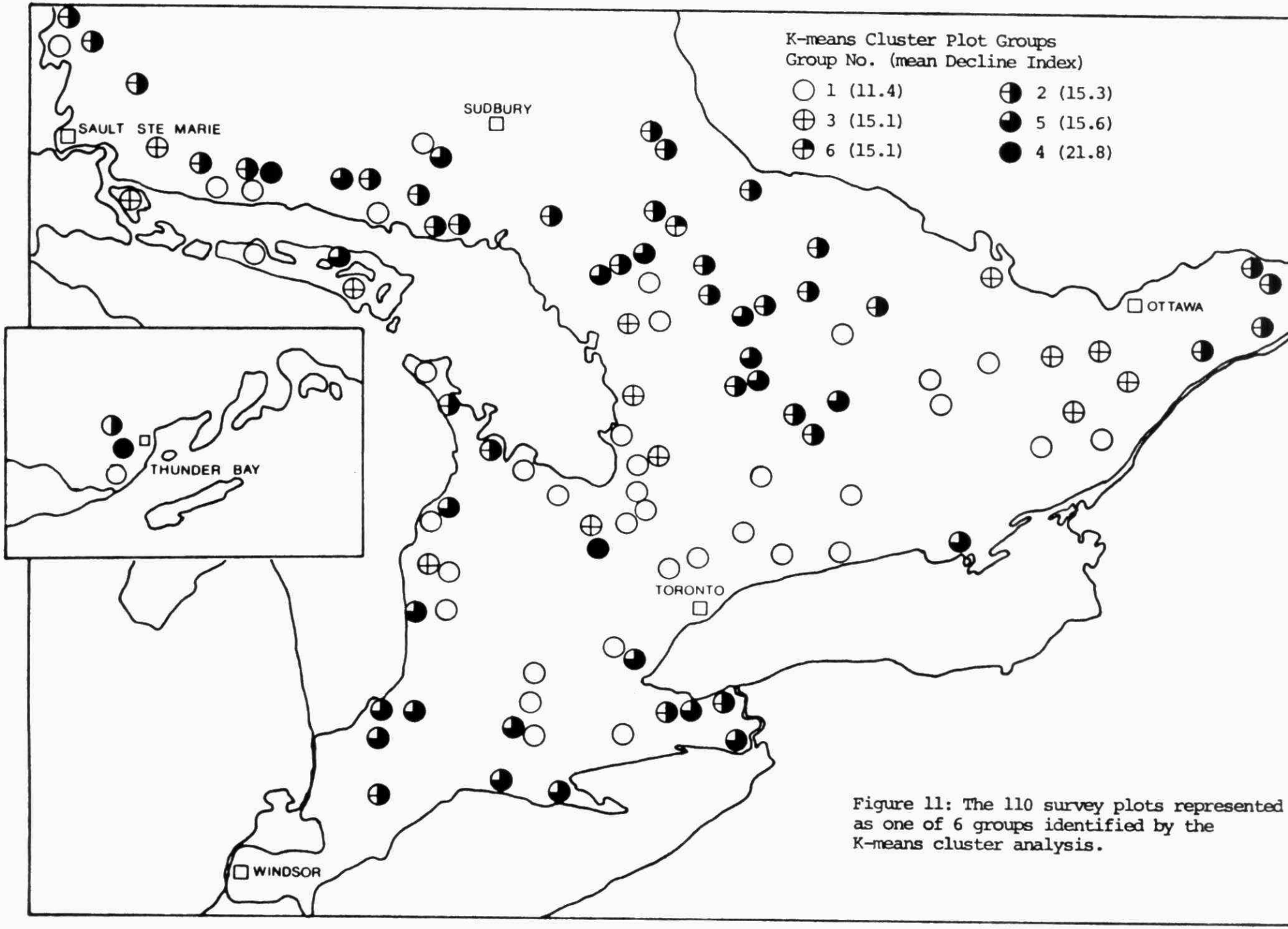


Figure 11: The 110 survey plots represented as one of 6 groups identified by the K-means cluster analysis.

Appendix I

Plot Description Forms

DATE: _____

PLOT NO.: _____

SURVEYORS:

Soils/Site

PLOT DESCRIPTION FORM

1. Location on the Slope:

C	Crest	U	Upper
M	Middle	L	Lower
T	Toe	D	Depression
F	Flatland		

2. Aspect (average condition for the plot):

3. Rock Outcrops (indicate % surface coverage to nearest 10%):

4. Surface Stoniness:

Frequency		Size	
N	non-stony	S	small
S	slightly	M	medium
M	moderately	L	large
V	very	B	boulders

5. Soils Data

SOIL PROFILE DESCRIPTION

Horizon	Thickness	Texture	G/g

Depth to Carbonates (cm):

Depth Organic Matter (avg. of 5 samples):

Moisture Regime:

0 0 1 2 3 4 5 6

pH Class (at 20 cm depth):

1 2 3 4 5 6

6. Soil Sample Number:

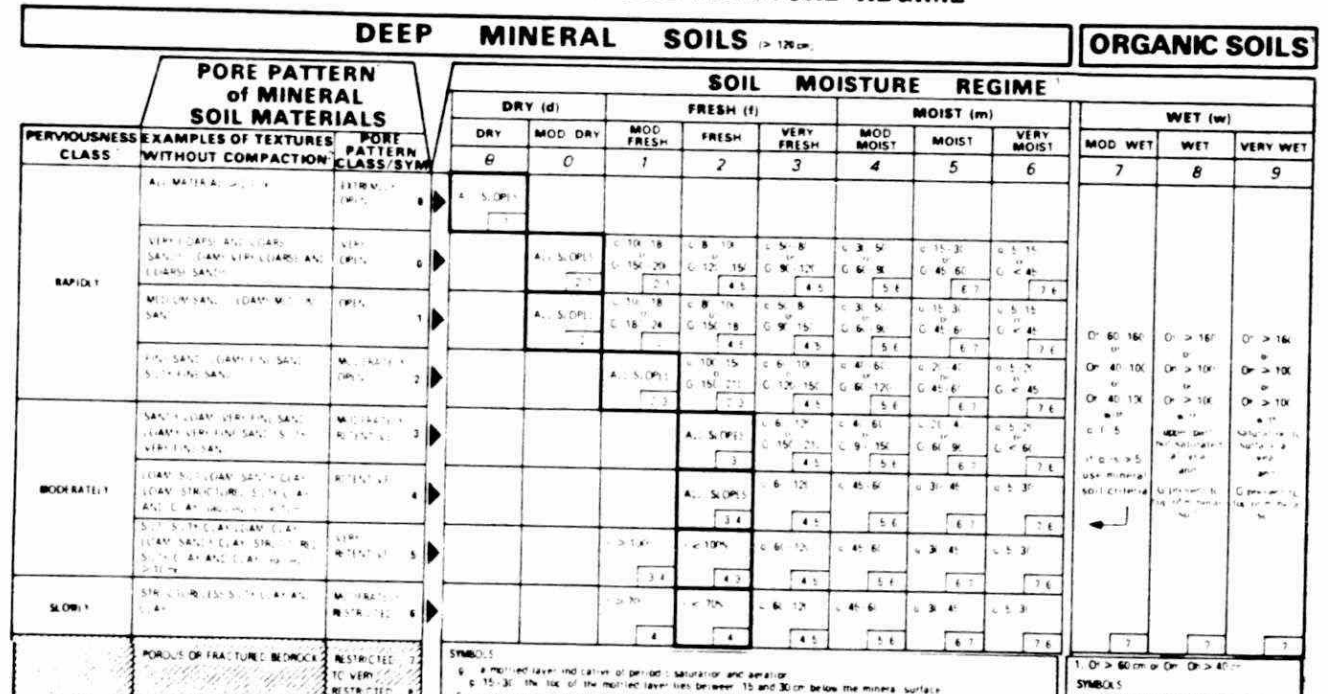
NOTES:

Appendix II

Mineral Soil Description Format

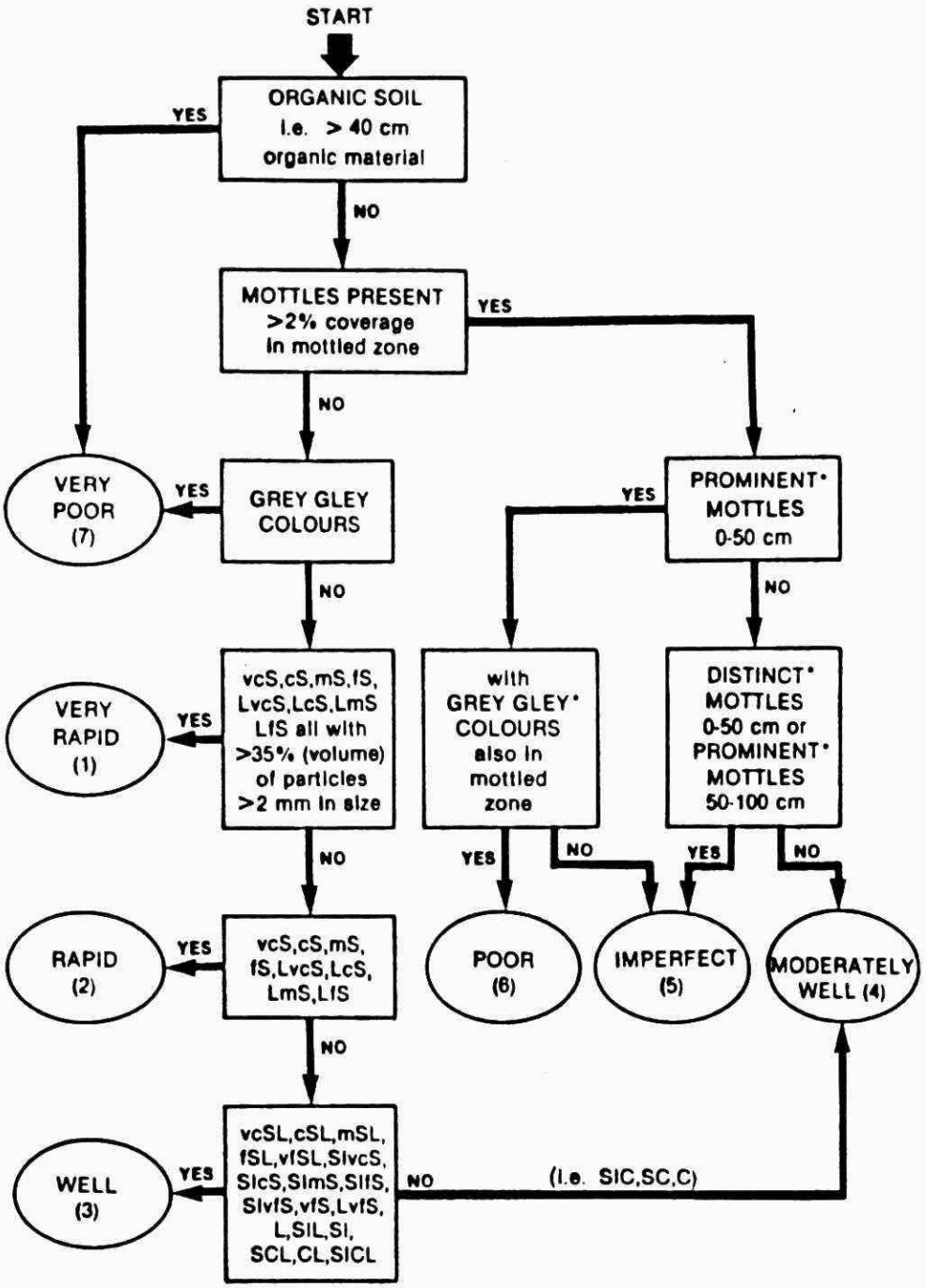
Appendix II

PORE PATTERN SOIL MOISTURE REGIME



From Ontario Ministry of Natural Resources, developed for the Ontario Physiographic System, Site Research Unit, Maple, Ontario.

soil drainage



S = SAND or SANDY
SI = SILT or SILTY
L = LOAM or LOAMY
C = CLAY

vc = very coarse
c = coarse
m = medium
f = fine
vf = very fine

examples:
vcS = very coarse SAND
LvfS = LOAMY very fine SAND
SICL = SILTY CLAY LOAM

N.B. In most recent soil surveys, the drainage classes are grouped to form four general drainage classes. VERY RAPID & RAPID = "RAPID", WELL & MODERATELY WELL = "WELL", IMPERFECT = "IMPERFECT" and POOR & VERY POOR = "POOR".

SOIL TEXTURE FIELD TEST

MOIST CAST TEST — Compress some *moist* soil by clenching it in your hand. If the soil holds together (i.e. forms a cast), then test the strength of the cast by tossing it from hand to hand. The more durable it is, the more clay is present.

RIBBON TEST — Moist soil is rolled into a cigarette shape and then squeezed out between the thumb and forefinger to form the longest and thinnest ribbon possible.

FEEL TESTS

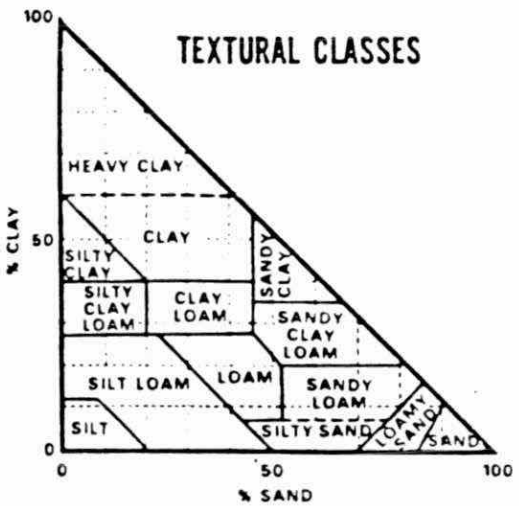
GRAININESS TEST — Soil is rubbed between thumb and fingers to assess the % sand. Sand feels grainy.

DRY FEEL TEST — Soils with > 50% sand. Soil is rubbed in the palm of the hand to dry it and to separate and estimate the size of the individual sand particles. The sand particles are then allowed to fall out of the hand and the amount of finer material (silt & clay) remaining is noted.

STICKINESS TEST — Soil is wetted and compressed between the thumb and forefinger. Degree of stickiness is determined by noting how strongly it adheres to the thumb and forefinger upon release of pressure and how much it stretches.

TASTE TEST — A small amount of soil is worked between the front teeth. Sand is distinguished as individual grains which grit sharply against the teeth. Silt particles are identified as a general fine grittiness, but individual grains cannot be identified. Clay particles have no grittiness.

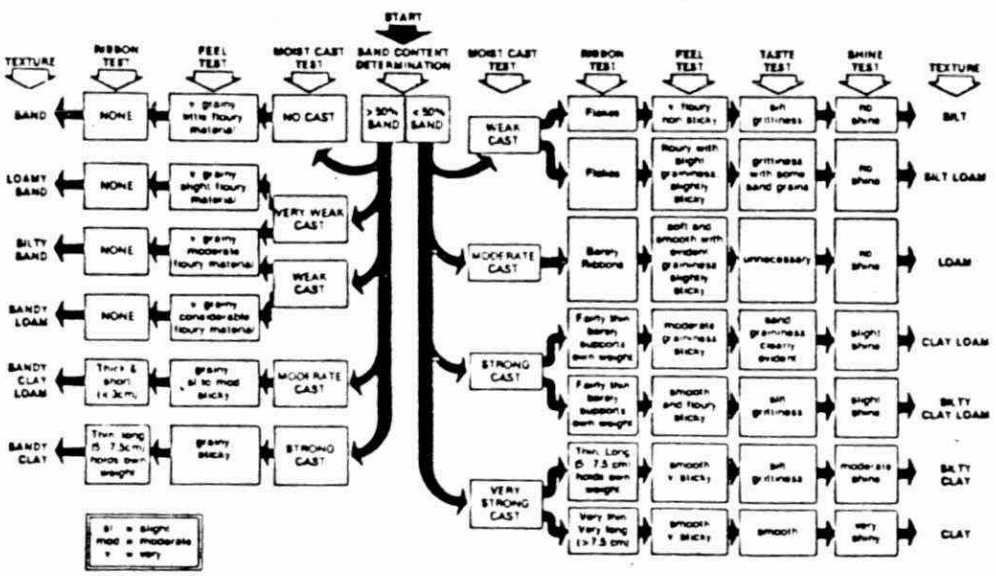
SHINE TEST — A small amount of moderately dry soil is rolled into a ball and rubbed once or twice against a hard, smooth object such as a knife blade or thumb nail. A shine on the ball indicates clay in the soil.



FIELD TEST CHARACTERISTICS OF SOIL TEXTURE CLASSES

TEXTURE CLASS	FEEL TEST	MOIST CAST TEST	RIBBON TEST	TASTE TEST	SHINE TEST
SAND	grainy with little floury material	no cast	none	unnecessary	unnecessary
LOAMY SAND	grainy with slight amount of floury material	very weak cast, no handling	none	unnecessary	unnecessary
SILTY SAND	grainy with moderate amount of floury material	weak cast, no handling	none	unnecessary	unnecessary
SANDY LOAM	grainy with considerable amount of floury material	weak cast, allows careful handling	none	unnecessary	unnecessary
LOAM	fairly soft and smooth with evident graininess	good cast, readily handled	barely begins to ribbon	unnecessary	unnecessary
SILT LOAM	floury with slight graininess	weak cast, allows careful handling	flakes, rather than ribbons	silt grittiness, some sand graininess	unnecessary
SILT	very floury	weak cast, allows careful handling	flakes, rather than ribbons	silt grittiness	unnecessary
SANDY CLAY LOAM	very substantial graininess	moderate cast	short and thick (< 3cm)	sand graininess clearly evident	slightly shiny
CLAY LOAM	moderate graininess	strong cast	fairly thin, breaks readily, barely supports own weight	sand graininess clearly evident	slightly shiny
SILTY CLAY LOAM	smooth and floury	strong cast	fairly thin, breaks readily, barely supports own weight	silt grittiness	slightly shiny
SANDY CLAY	substantial graininess	strong cast	thin, fairly long (5 - 7.5 cm), holds own weight	sand graininess clearly evident	moderately shiny
SILTY CLAY	smooth	very strong cast	thin, fairly long (5 - 7.5cm) holds own weight	silt grittiness	moderately shiny
CLAY	smooth	very strong cast	very thin, long (7.5 cm)	smooth	very shiny

FINGER ASSESSMENT OF SOIL TEXTURE



Appendix III

Tree Condition Assessment Form

Tree Condition Assessment Form

Appendix III

Plot: Location:
Date: Weather:
Crew:

Key to Additional Observations
1.Frost cracks 2.Conks 3.Open wounds 4.Insects
5.Mites 6. Cankers 7.Root rot 8.Heart rot 9.Others

Tree No.	Species Code	Diam (cm)	Height (m)	Co-ordinates Angle (deg)	Co-ordinates Dist (m)	Percent Dead Branches	Percent Slight Chlorosis	Percent Strong Chlorosis	Crown Class Rating	Percent Small Leaves	Decline Index	Additional Observations 1	2	3	4	5	6	7	8	9	Age
1											0										
2											0										
3											0										
4											0										
5											0										
6											0										
7											0										
8											0										
9											0										
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22											0										
23											0										
24											0										
25											0										

Appendix IV

Crown Condition Classification System

For Coniferous and Deciduous Trees

Rating	Description
1	Near perfect specimen tree
2	High quality forest tree with self pruning of shaded branches
3	Tree in good condition, may have 1 or 2 dead branches
4	Tree in fair to moderate condition with 3 or more dead branches
5	Up to one half of crown dead
6	One half to 75% of crown dead
7	75 - 90% of crown dead
8	Over 90% of crown dead, some branches retaining foliage
9	Branches with few live needles/leaves still attached
10	Tree dead

Appendix V

Key to Column 9 - Additional Observations

b	- burl
bb	- broken branch
bc	- broken crown
br	- butt rot
bt	- branches thinning
c	- clump
ds	- double stemmed
f	- fungus (unidentified)
fi	- fomes igniarius
fs	- fomes spp.
g	- grafted to another tree
lm	- leaf miner
mb	- maple borer
ng	- nectria galligena
po	- poria obliqua
ps	- polyporus spp.
s	- suppressed
sh	- sapsucker holes
sm	- spindlegall mites
sr	- stilted roots
t	- triple stem
tf	- thinning foliage
th	- tap holes

SD
397
.S775
M35
1989